MODULATION OF JOINT ACTION CORRESPONDENCE EFFECTS BY TASK CONTEXT: EXAMINATION OF THE CONTRIBUTIONS OF SOCIAL, SPATIAL, AND RESPONSE DISCRIMINATION FACTORS

by

Melanie Yah-Wai Lam

B.A., Simon Fraser University, 2003
M.Sc., The University of British Columbia, 2006

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Kinesiology)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

January 2013

© Melanie Yah-Wai Lam, 2013
Abstract

The aim of this dissertation was twofold: (1) to examine task co-representation and joint action in efforts to identify necessary preconditions under which shared representations are formed and (2) to determine whether alternative explanations can account for the social Simon effect (SE). Using joint Simon effect protocols (e.g., Sebanz & Knoblich 2003), we began (Study 1) by showing that when paired participants responded to the same stimulus-response alternative, the joint SE was absent. When participants performed under a competitive context (Study 2), the joint SE was elicited, even though co-representation would have been disadvantageous with respect to the task goal. Next, we examined the influence of spatial and response discrimination factors on the joint action correspondence effect. Our first investigation (Study 3) did not support the assumption that the co-actor may be providing a reference for the spatial coding of alternative responses. Using Ansorge and Wühr’s (2004) response discrimination hypothesis as a framework, we showed in subsequent studies (Study 4 & 6) that a SE could be elicited in a Go/No-Go task when spatial codes were used to discriminate between alternative responses. This was demonstrated when a standard 2-choice task preceded a Go/No-Go task and when participants performed two independent tasks alongside each other. Examination of event-related potentials pertaining to action inhibition suggested reduced action suppression on no-go trials when performing with a co-actor compared to performing with alone under these independent task conditions. In a final study (Study 7), we explored task co-representation using a different experimental paradigm—the response-precuing task. Our results did not provide clear evidence for task co-representation. In cases where the ‘social’ SE was not observed, we propose that a form of ‘social loafing’ or an individualistic mindset approach to the joint action task may have been
in operation. Our overall findings encourage further investigation of how task context can modulate the joint SE and highlights how an *individualistic mindset* can potentially preclude co-representation.
Preface


Chapters 2-8 and Appendix A detail the experimental findings of studies conducted in the Perceptual-Motor Dynamics Laboratory at the University of British Columbia (UBC). All work was conducted under the supervision of Dr. Romeo Chua. With respect to the work conducted, I was responsible for experimental design, data collection, and data analysis and manuscript preparation.

All of the experimental methods used to collect the data included in Chapters 2-8 and Appendix A were approved by the University of British Columbia’s Behavioural Research Ethics Board (UBC BREB Number: H03-80057).
Table of Contents

Abstract ................................................................................................................................. ii
Preface ................................................................................................................................ iv
Table of Contents .................................................................................................................... v
List of Tables .......................................................................................................................... ix
List of Figures ........................................................................................................................ x
Acknowledgements .............................................................................................................. xiv
Dedication .............................................................................................................................. xvi

1 Chapter: Introduction ......................................................................................................... 1
  1.1 Perception-Action Coupling: A Mediator for Social Understanding and Social Interaction 4
    1.1.1 Internal Descriptions of What We See and What We Do ........................................ 5
    1.1.2 A Mechanism for Joint Action: The Mirror Neuron System .................................. 7
    1.1.3 Ideomotor Theory: How Perception and Motor Action are Related ....................... 10
  1.2 Let’s Share this World Together ................................................................................... 12
    1.2.1 Joint Action and Co-Representation Defined ......................................................... 12
    1.2.2 Gathering Information to Conform One’s Behaviour with Another’s ..................... 14
    1.2.3 Task Sharing and Co-Representation .................................................................... 16
  1.3 What are the Prerequisites for Co-Representation? ..................................................... 20
    1.3.1 Co-Representation and the Biological Agent ....................................................... 20
    1.3.2 Is Physical Presence Required or is Belief Enough? ............................................. 22
    1.3.3 The Impact of Positive and Negative Relationships on Co-Representation .......... 23
    1.3.4 Forming a Shared Representation of Symbolic Information ................................ 24
  1.4 Aims of the Current Studies ......................................................................................... 25

2 Chapter: Study 1 - Influence of Stimulus-Response Assignment on the Joint Simon Effect .............................................................................................................. 30
  2.1 Introduction .................................................................................................................. 30
  2.2 Methods ....................................................................................................................... 32
    2.2.1 Participants ............................................................................................................ 32
    2.2.2 Apparatus ............................................................................................................. 33
6 Chapter: Study 5 - The Power of the Pointing Finger: Do Social Pointing Stimuli Enhance the Social Simon Effect? .......................................................... 103

6.1 Introduction .................................................................................. 103
6.2 Methods ....................................................................................... 104
  6.2.1 Participants ............................................................................ 104
  6.2.2 Apparatus .............................................................................. 104
  6.2.3 Stimuli .................................................................................. 105
  6.2.4 Procedures ........................................................................... 106
6.3 Results .......................................................................................... 107
6.4 Discussion .................................................................................... 108

7 Chapter: Study 6 - Spatial Response Discrimination Can Elicit a Joint Simon Effect in an Independent Task ......................................................... 110

7.1 Introduction .................................................................................. 110
7.2 Methods ....................................................................................... 119
  7.2.1 Participants ............................................................................ 119
  7.2.2 Apparatus .............................................................................. 119
  7.2.3 Stimuli .................................................................................. 120
  7.2.4 Procedures ........................................................................... 120
7.3 Results .......................................................................................... 126
  7.3.1 Behavioural Results ................................................................. 127
  7.3.2 Electrophysiological Data ......................................................... 129
    7.3.2.1 Go and No-Go P3 Components for the JA Group .......... 131
    7.3.2.2 Go and No-Go P3 Components for the JOK Group ....... 135
    7.3.2.3 Go and No-Go P3 Components for the JSK Group ...... 138
7.4 Discussion .................................................................................... 141
  7.4.1 Behavioural Task Performance ................................................ 142
  7.4.2 Electrophysiological Findings .................................................. 145
7.5 Bridging Summary ...................................................................... 153
8 Chapter: Study 7 - Joint Action Effects in a Social Response-Precuing Task .... 155

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1 Introduction</td>
<td>155</td>
</tr>
<tr>
<td>8.1.1 The Response Precuing Paradigm</td>
<td>159</td>
</tr>
<tr>
<td>8.1.2 The Social Response-Precuing Effect: Rationale and Hypotheses</td>
<td>161</td>
</tr>
<tr>
<td>8.2 Experiment 7A: Group Condition</td>
<td>165</td>
</tr>
<tr>
<td>8.2.1 Methods</td>
<td>165</td>
</tr>
<tr>
<td>8.2.1.1 Participants</td>
<td>165</td>
</tr>
<tr>
<td>8.2.1.2 Apparatus</td>
<td>165</td>
</tr>
<tr>
<td>8.2.1.3 Stimuli</td>
<td>166</td>
</tr>
<tr>
<td>8.2.1.4 Procedures</td>
<td>171</td>
</tr>
<tr>
<td>8.2.1.5 Results</td>
<td>172</td>
</tr>
<tr>
<td>8.3 Experiment 7B: Solo Condition (2-Choice Task)</td>
<td>174</td>
</tr>
<tr>
<td>8.3.1 Methods</td>
<td>176</td>
</tr>
<tr>
<td>8.3.1.1 Participants</td>
<td>176</td>
</tr>
<tr>
<td>8.3.1.2 Apparatus</td>
<td>176</td>
</tr>
<tr>
<td>8.3.1.3 Stimuli</td>
<td>176</td>
</tr>
<tr>
<td>8.3.1.4 Procedures</td>
<td>176</td>
</tr>
<tr>
<td>8.3.1.5 Results</td>
<td>177</td>
</tr>
<tr>
<td>8.4 Discussion</td>
<td>178</td>
</tr>
</tbody>
</table>

9 Chapter: General Discussion and Conclusion .................................. 187

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1 Summary of Conducted Studies</td>
<td>190</td>
</tr>
<tr>
<td>9.2 Another Mind Can Lighten the Load: Why Co-Represent When You Can Have a Free Ride?</td>
<td>193</td>
</tr>
<tr>
<td>9.3 Limitations</td>
<td>199</td>
</tr>
<tr>
<td>9.4 Conclusion</td>
<td>201</td>
</tr>
</tbody>
</table>

Bibliography ............................................................................................. 203

Appendices ................................................................................................... 224

Appendix A Solo Performance in a 4-Choice Response-Precuing Task ............ 224

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1 Introduction</td>
<td>224</td>
</tr>
<tr>
<td>A.2 Methods</td>
<td>225</td>
</tr>
<tr>
<td>A.3 Results</td>
<td>226</td>
</tr>
</tbody>
</table>
List of Tables

Table 5.1 Table of experimental conditions, task sequences and predictions made by the response discrimination hypothesis (RDH) and a co-representation standpoint for each of the four task sequence groups ................................................................. 80

Table 7.1 Mean RT (go trials) on Corresponding (C) and Non- Corresponding (NC) trials in the solo and group conditions for the three groups (JA, JOK, JSK). *The correspondence effect = RT non-corresponding - RT corresponding. ........................................................................ 128

Table 7.2 Mean P3 amplitudes for the JA group. The mean amplitudes and mean standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding) for the JA group .................. 133

Table 7.3 Mean P3 amplitudes for the JOK group. The mean amplitudes and standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding) ......................... 137

Table 7.4 Mean P3 amplitudes for the JSK group. The mean amplitudes and standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding) ......................... 140
List of Figures

Figure 2.1 Mean RT on corresponding and non-corresponding trials for the IGNG, TC, JD and JS task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 38 ms and 37 ms for the IGNG task; 24 ms and 26 ms for the TC task; 27 ms and 27 ms for the JD condition; and 28 ms and 27 ms for the JS condition.......................... 36

Figure 3.1 Mean RT on corresponding and non-corresponding trials for the IGNG, TC, and JC task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 6 ms and 6 ms for the IGNG task; 11 ms and 8 ms for the TC task; and 4 ms and 5 ms for the JC condition................................................................. 51

Figure 4.1 Seating arrangement of participant (A) and confederate (B) in the IGNG, TC, JA and JA2 tasks. ................................................................. 64

Figure 4.2 Mean RT on corresponding and non-corresponding trials for the IGNG, TC, JA and JA2 task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 10 ms and 9 ms for the IGNG task; 11 ms and 8 ms for the TC task; 10 ms and 8 ms for the JA task; and 13 ms and 11 ms for the JA2 condition................................. 68

Figure 5.1 Mean RT on corresponding and non-corresponding trials for the IGNG task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 20 ms and 24 ms for the IGNG-BASELINE task; 19 ms and 21 ms for the IGNG-PRETEST task; 18 ms and 17 ms for the IGNG-OPPOSITE KEY task; and 18 ms and 18 ms for the IGNG-POSTTEST task. ........................................................................................................ 87

Figure 5.2 Mean RT on corresponding and non-corresponding trials for the TC task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 22 ms and 22 ms for the IGNG-BASELINE task; 20 ms and 20 ms for the IGNG-PRETEST task; 21 ms and 22 ms for the TC-EXPOSURE task; and 17 ms and 21 ms for the IGNG-POSTTEST task................................................................. 89
Figure 5.3  Mean RT on corresponding and non-corresponding trials for the JA task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 22 ms and 23 ms for the IGNG-BASELINE task; 19 ms and 20 ms for the IGNG-PRETEST task; 17 ms and 17 ms for the JA-EXPOSURE task; and 22 ms and 19 ms for the IGNG-POSTTEST task.

Figure 5.4  Mean RT on corresponding and non-corresponding trials for the JA-TC-JA task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 27 ms and 27 ms for the IGNG-BASELINE task; 17 ms and 13 ms for the JA-PRETEST task; 23 ms and 30 ms for the TC-EXPOSURE task; and 18 ms and 23 ms for the JA-POSTTEST task.

Figure 6.1  Example of the pointing finger stimuli used in the experiment.

Figure 6.2  Mean RT on corresponding and non-corresponding trials for the IGNG, JA and TC conditions. The SEM on corresponding and non-corresponding trials, respectively, were 12 ms and 12 ms for the IGNG condition; 12 ms and 11 ms for the JA condition; and 15 ms and 15 ms for the TC condition.

Figure 7.1  Experimental setup. (A) A schematic of the solo condition in which participants performed the IGNG task. (B) A schematic of the group condition in which participants performed alongside the co-actor who initiated each trial using the same response key (JSK task). (C) A schematic of the group condition in which participants performed alongside the co-actor who either initiated each trial using the opposite response key (JOK task) or performed the complementary part of the Simon task (JA task).

Figure 7.2  Temporal sequence of events in a trial for the JA, JOK and JSK tasks. The one difference in the JOK and the JSK tasks was the addition of a cue to start presented at the beginning of the trial.
Figure 7.3  Mean RT on corresponding and non-corresponding trials for the JA, JOK and JSK groups. The SEM on corresponding and non-corresponding trials for the solo and group conditions, respectively, were 11 ms, 15 ms, 13 ms and 13 ms for the JA group; 17 ms, 16 ms, 18 ms and 18 ms for the JOK group; 12 ms, 12 ms, 14 ms, 10 ms for the JSK group.

Figure 7.4  Grand averages showing Go P3 (A) and No-Go P3 (B) for the JA group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.

Figure 7.5  Grand averages showing Go P3 (A) and No-Go P3 (B) for the JOK group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.

Figure 7.6  Grand averages showing Go P3 (A) and No-Go P3 (B) for the JSK group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.

Figure 8.1  Experimental setup. Gray shaded area indicates parts of the display obscured from participants’ view.

Figure 8.2  Stimulus sequence in each trial. Trials started with the presentation of a warning stimulus. After 750 ms, the precue stimulus appeared for 1500 ms then the target appeared in one of four placeholder positions for 1000 ms or until a response was detected. The inter-trial-interval (ITI) was 1000 ms.

Figure 8.3  Example of stimulus displays for each precuing type when the target indicated a right index finger response. Fixation and placeholders are black instead of gray for the ease of viewing.
Figure 8.4  Mean RT for each precue type in the group condition. The SEM for unprepared, hand, neither, finger and full precue types were 18 ms, 17 ms, 19 ms, 16 ms and 17 ms, respectively. ................................................................. 173

Figure 8.5  Mean RT for each precue type in the solo condition (2-choice). The SEM for unprepared, hand, neither, finger and full precue types were 38 ms, 34 ms, 37 ms, 39 ms and 35 ms, respectively ................................................................. 177

Figure 8.6  Illustration of how set size is reduced for each precue type in a response-precuing task under the solo and group conditions. For example, participant A is instructed to respond to targets that appear in the two leftmost response positions (circled). For the unprepared precue type, all four response positions are highlighted but participant A is only responding to two of those four response positions thus reducing task-relevant information. ................................................................. 180

Figure A.1  Mean RT for each precue type in the solo condition (4-choice). The SEM for unprepared, hand, neither, finger and full precue types were 18 ms, 17 ms, 18 ms, 16 ms and 16 ms, respectively ................................................................. 227
Acknowledgements

I have been hard pressed to decide who, exactly, I would mention in this section of my thesis. That is not to say that I am uncertain as to who has played a role in encouraging, supporting and loving me along my journey through graduate school. I think that it is natural for one to thank those who are presently in their life as the significance of others requires one to pause and take a moment to reflect back on the past. Sometimes this can be challenging but I feel that it would be a disservice not to express my gratitude to every person who has touched my life in some way, shape or form. They may not be a part of my life anymore but they were still a part of it at some point in time – the words that we shared and our interactions that were ever so meaningful. I am who I am today because of you. I am humbly blessed and grateful for your presence and the impact that each of you has had on me. And so I thank you all.

I would like to explicitly thank a few specific individuals who hold a special place in my heart. First and foremost, my parents and my sister, Aimee for their unconditional love and support. Thank you for never questioning my decision to be a student for as long as I have been. I have never had any regret about the choices I have made throughout this process and I am so appreciative that none of you have ever doubted me.

I am indebted to my supervisory committee, Dr. Franks and Dr. Hodges. Dr. Franks, you have always encouraged us not to take what we read at face value but to use our critical faculties to thoroughly question and analyze the evidence that we are presented with and the conclusions that are made. I sometimes find myself reading articles and taking the viewpoints as fact without a second thought but I am definitely more cognizant of this bad habit because of you. Dr. Hodges, Nikki, I am ever so grateful for your guidance on both an academic and personal level. You may not know it but you have had a tremendous impact on my life. I have an insurmountable respect and admiration for your ability to maintain such a healthy balance between your career and your family and to have as much success as you do academically. I value the time that you have taken to provide me with the constructive feedback necessary to produce a thesis that I am so very proud of.
Finally, Dr. Chua. Romeo, to think that we have known each other for ten years and worked together for almost nine; time flies. I can honestly say that I am going to feel a little lost not coming into the lab every day. You have been my strongest advocate and have always gone to bat for me. You have served as a sounding board to improve and refine my research ideas and never made me feel foolish for the basic questions I would often ask. Please know that your strong work ethic and dedication to us, your graduate students, never went unnoticed; I promise to emulate these great qualities. Thank you for balancing our conversations between formal discussions about my research and informal discussions about current events over coffee. Thank you for providing me with constructive and supportive feedback on my work, almost always, within 24 hours. Thank you for always conveying to me that you wanted me to succeed. And thank you for making my graduate school experience a positive and memorable one.

On a final note, I would like to extend my gratitude to Dr. Weeks. Dan, the stars were aligned when Dr. Thornton told me that the new chair of Psychology was seeking out a research assistant. I am ever so grateful that you took the time to mentor me for those two years. Thank you for seeing whatever quality in me that you felt would be a good fit for grad school.
Dedication

I dedicate this thesis to my parents and my sister, Aimee.
1 Chapter: Introduction

“Man is by nature a social animal; an individual who is unsocial naturally and not accidentally is either beneath our notice or more than human. Society is something that precedes the individual. Anyone who either cannot lead the common life or is so self-sufficient as not to need to, and therefore does not partake of society, is either a beast or a god.”

Aristotle, Politics

We humans are social creatures. Our innate drive for affiliation means that we frequently find ourselves interacting with others on some level. We may engage in a cooperative activity with a family member or a friend, someone we are well-acquainted with but the beauty of being human is that we are also able to act with complete strangers. Coordinating our actions with others is an amazing feat if we take a moment to appreciate that separate neural system are controlling the bodily movements that allow two individuals to achieve a shared goal. What cognitive mechanisms are at play in successful joint action? What many of us are unaware of is the ‘automatic’ influence others have on our behaviour when we come into contact with them. For example, when someone leans over to whisper something to us, we have a tendency to whisper back only to question ourselves for doing so when we realize that an “inside” voice was not necessary (see Chartrand & Bargh, 1999, for the Chameleon effect). When we watch a live sporting event like boxing and we find ourselves clenching our fists, making slight jab motions and flinching as if we were the one in the ring. These occurrences demonstrate that the observation of action can have a direct effect on motor behaviour.

Action observation allows us to understand another person’s action goals. When we watch someone execute an action the same cortical circuits involved in carrying out the
observed action are automatically activated (Fadiga et al., 2005; Hari et al., 1998; for an opinion piece see Rizzolatti et al., 2001). Motor simulation, also referred to as ‘motor resonance’, provides a means of deriving information to understand or predict another person’s actions (Blakemore & Decety, 2001; Wilson & Knoblich, 2005). While there is unquestionable value in exploring how the link between perception and action contributes to social understanding, how it facilitates social interaction is equally deserving of our attention. How we relate to each other is not through observation, simulation and/or imitation alone. We also partake in activities that require the coordination of action in efforts to achieve some common goal (e.g., moving a table, playing a piano duet).

The studies presented in this dissertation were driven by an inventive series of experiments that explored how individuals influence each other’s performance in task sharing. Sebanz et al. (2003a) investigated whether individuals form shared representations of another person’s actions in a turn-taking, or complementary, task even though that person’s actions has no direct bearing on their own; to do so they utilized the Simon task. In a typical Simon task (Simon & Rudell, 1967), coloured stimuli can appear on either the left or right side of a computer screen. Participants are instructed to make a left- or right-key response to the non-spatial task relevant attribute of the stimulus (e.g., press the left key when stimulus is red, press the right key when the stimulus is green). Even though stimulus location was irrelevant to the task, responses were faster and more accurate when stimulus and response positions corresponded than when they did not correspond (Simon, 1969). This finding is referred to as the Simon effect (SE) (De Jong et al., 1994; Lu & Proctor, 1995; Simon & Rudell, 1967). By distributing this 2-choice Simon task between two participants, Sebanz et al. were able to address whether one’s performance is affected by another person’s
task if a shared representation has been formed. What they found was that performance in the group condition was comparable to when participants completed the entire task on their own (Sebanz et al., 2003a; 2005a); this has been called the joint action effect or the social Simon effect (SSE). Moreover, there was no Simon effect (SE) in a corresponding solo condition where one sole participant performed the exact same Go/No-Go task as in the group condition. The claim is that when someone performs in a complementary task with another person, one cannot help but automatically represent the task requirements and goals of the co-actor, even if it is detrimental to their performance (Sebanz et al., 2006a). Subsequent studies have set out to identify necessary conditions for co-representation\(^1\) to occur. For example, it has been shown that the SSE only emerges when participants engaged with a biological agent not a non-biological agent (Tsai & Brass, 2006) unless the actions executed by the non-biological agent are perceived as having human-like qualities (Müller et al., 2011). There is also evidence to suggest that it is enough for participants to believe they are interacting with an intentional agent for a shared representation to be formed (Tsai et al., 2008; cf., Welsh et al., 2007).

What now follows is a brief review of how the perception and action link contributes to our understanding of what another person is doing and why they are doing it during action observation. We will also describe what joint action is and what co-representation entails. A brief summary will provide the necessary details about Sebanz et al.’s (2003a) original joint action study which addressed how another person’s action might affect one’s own in a complementary task. Finally, we will review some of the studies that have identified some of

\(^1\) The terms ‘co-representation’ and ‘shared representations’ will be used interchangeably throughout this dissertation. It will refer to a means by which predictions can be made about another person’s response.
the rudimentary conditions for participants to co-represent what their partner is supposed to do.

1.1 Perception-Action Coupling: A Mediator for Social Understanding and Social Interaction

Your typical morning routine may consist of having a cup of coffee and checking your email on your home computer. These particular activities do not involve the coordination of our bodily movement in a complex, dynamic environment. You reach out for your cup of coffee on the kitchen counter and you visually track the cursor on your computer monitor. It is the reciprocal relationship between the processing of sensory information and the production of an action, better known as perception-action coupling that gives rise to successful action outcome. Gibson (1979) stated that, “we must perceive in order to move, but we must also move in order to perceive” (p. 223). To think that our brains have evolved in such a way that we are able to transform sensory information into patterns of motor coordination to regulate motor activity is a remarkable capability (Sperry, 1952). Only over the past decade has the significance of perception-action coupling as a fundamental mechanism of motor cognition been recognized (Sommerville & Decety, 2006). The processes involved in motor cognition allow us to plan, prepare and execute our own actions and to anticipate, predict and understand the actions of others. Neuroimaging studies have offered supportive evidence for the idea that there are shared representations between self and others’ actions (Decety & Sommerville, 2003; Jeannerod, 1999). Common areas of activation have been observed in the brain during one’s own actions as well as during the observation of someone else’s actions (Buccino et al., 2004; Grèzes et al., 2003; Rizzolatti et al., 1996). In the following
sections, we will briefly consider how these processes mediate successful interaction with others.

1.1.1 Internal Descriptions of What We See and What We Do

Gibson’s theory of “affordances” has been influential, yet controversial, in developing an appreciation for the inseparability of perception and action (1979). The term affordance refers to the properties in the environment that can be perceived to reveal prospective, yet well-defined, behaviour. According to Gibson, the possibilities for action in a given environment are relative to the capabilities of the perceiving actor (person or animal). For example, in a stair climbing study, Warren (1984) showed that an individual’s perception of climb-ability was dependent on which set of stairs best matched their body size. Another attribute of affordances is that they are readily available at all times; they do not cease to exist simply because the actor does not have the ability to perceive them. Take for example humans and dogs that dwell in the same physical environment (a house) yet their experiences within it are unique. To a dog, the space underneath the desk is a safe place to sleep, whereas, to a human, it is where they place their feet while they complete work. We may also see differences within a species. While a stick to one dog represents an object that can be played fetch with, to another it may be seen as something to chew on in the yard. Despite Gibson’s optimism that his “ecological” theory of affordances would be embraced by other domains, his assumption that the “values” and “meanings” of objects and events in the environment are directly perceived clashed with cognitive psychology’s emphasis on internal representations (Zhang & Patel, 2006).
Internal representations can be described as a copy of an external stimulus; a mental representation. Our ability to perceive and understand properties in the environment (e.g., objects, faces, scenes and events) are mediated by these internal representations which are generated by our sensory organs. Gibson’s insistence that affordances are physical properties in the environment that need to be directly perceived makes it difficult to assume that he would accept that the process of imagining is comparable to perceiving. An internal construct relating to perception that is carried out by mental/computational processes would be challenging notion for him to accept. Shepard (1984) made a bold attempt to reconcile Gibson’s (1979) contention that the perceptual system becomes attuned to the environment with the idea that higher processes (e.g., interpretation) are necessary to make sense of our environment. He examined the ecological constraints of internal representation and argued that not only perceiving but also “remembering imagining, planning and thinking” are all similarly influenced by internalizations of long-enduring constraints in the external world (p. 433). According to Shepard, “instead of picking up the invariants that are wholly present in the sensory arrays, as a result of biological evolution and perceptual and cognitive learning, an organism is tuned to resonate to the invariants that are significant for it” (p. 433). This resonance behaviour allows information about the environment, and the organism’s relation to it, to be deeply internalized, or represented, and when external information is unavailable, system excitation is still possible by accessing those representations (e.g., by way of imagination). Evidence that internal representations hold information about the appearance of physical objects, events and scenes, even in their absence, has been demonstrated in mental rotation (Shepard & Metzler, 1971) and image scanning (Kosslyn et al., 1978) tasks. More specifically, these studies favour the postulation that the internal representation of a given
object is manipulated in much the same way it would if one physically executed the operation. The concept of an internal representation also extends to action in which representations for acting and imagining are deemed to be one and the same thing (Jeannerod, 1995).

Action representations have two critical properties (Jeannerod, 2007). First, they are comparable to real action. The motor system deems them as real action simulation. Second, they are not only built from internal cues but also external ones. When we watch someone performing an action, the action representation generated and stored in our motor system is automatically retrieved as if we are actually executing those actions. This latter property of action representations is particularly important for social interaction because it suggests that the observer and the observed share similar representations of the same action which can answer questions such as ‘what’ and ‘why’ of a particular action. When we look at someone’s foot kicking a ball, a similar population of neurons that control the execution of the kicking movement becomes active in the observer’s motor areas. We understand the observed action because the associated action representation is activated in our own brain so long as the degree that the perceived and represented actions are similar (Knoblich & Flach, 2003). The notion that there are shared representations between perceived and generated actions, and actions produced by oneself and others, is supported by the discovery of a neural substrate that activates under each of these conditions: the mirror neuron system.

1.1.2 A Mechanism for Joint Action: The Mirror Neuron System

The mirror neuron system (MNS) is a neural substrate thought to represent the biological basis for social cognition (Gallese et al., 2004). First documented in a study
measuring the neural activity in the premotor cortex (area F5) of macaque monkeys, Rizzolatti and colleagues (1996) detected a set of neurons that discharged when these monkeys executed an action (e.g. reached for a peanut or pulled a lever) and when they sat motionless watching another (monkey or human) perform that same action. These neurons were subsequently called ‘mirror neurons’ (MNs) for their characteristic quality of activating to both observed and performed actions (Oberman et al., 2006). While single-unit electrode recordings were used to first discover MNs in the monkey brain, this technique was regarded as too invasive to identify whether a similar mirror system existed in humans. As a result, indirect evidence from neurophysiological and brain imaging studies were relied on. Neurophysiological studies have examined EEG rhythms, more specifically the so-called mu wave, which is generated and recorded from the sensorimotor cortex (Gastaut & Bert, 1954; Cochin et al., 1999). Mu wave suppression has been used as an index of MN activity and studies as early as 1954 have shown that when actions are self-produced, observed and imagined, the mu wave will be reduced (Gastaut & Bert, 1954; Cochin et al., 1998; Pineda et al., 2000); this is in contrast to when an action is pantomimed (Muthukumaraswamy et al., 2004). Transcranial magnetic stimulation (TMS) has been used to show modulations in motor evoked potentials (MEPs) in an observer’s muscles that correspond to those used by the actor (Fadiga et al., 1995), and magnetoencephalography (MEG) to identify similar overlapping areas of activation in the brain during observation and imitation of an action (Hari, 1998). The brain imaging studies have used positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) for the anatomical localization of the human MNS (Decety & Chaminade, 2003; Decety et al., 1997; Grafton et al., 1996; Grèzes et al., 1998, 2003; Iacoboni et al., 1999; Rizzolatti et al., 1996). More recently, however, Mukamel
et al. (2010) have provided direct electrophysiological evidence for a MNS in humans. They were able to record from single neurons in the brains of epileptic patients during the presentation of one of two types of video showing either precision grips or whole hand prehensions. They observed neurons that discharged during both the observation and execution of one type of action (e.g., precision grip), showing similar behaviour to broadly congruent mirror neurons in monkeys (Gallese et al. 1996).

One of the functional roles of the MNS is a kind of observation-execution matching system. It has been suggested that the MNS generates internal representations of action which observed actions are mapped onto; this is how the actions of another person are thought to be understood. For example, while watching our friend cutting an apple, the neural network involved in actually executing that same action becomes active. Since the outcome of those actions are known to us, by way of this observation-execution matching system, we understand what the other person is doing (Gallagher, 2005; Gallese & Goldman, 2002).

Neurophysiological and brain imaging studies have also provided supportive evidence in favour of the existence of this observation-execution matching system. In a TMS experiment, Fadiga et al. (1995) showed when participants observed grasping movements during the observation of intransitive movements (e.g., hand grasping), there was an increase of MEPs recorded from the same muscles one would normally use to produce the observed movements. This illustrates that the mere observation of action facilitates the motor system. In addition, investigations using positron emission tomography (PET) have found significant activation of the left inferior frontal gyrus (Broca's area), the left superior temporal sulcus and the inferior parietal lobule during the observation of grasping actions (Grafton et al., 1996; Rizzolatti et al., 1996). While the observation of action allows one to appreciate what
someone is doing, there is also suggestion that the MNS allows one to infer why someone is doing it (Gallese & Goldman, 1998).

The MNS not only codes another person’s actions but also the intent of their actions (Gallese & Goldman, 1998). Iacoboni et al. (2005) investigated whether activity in the MN areas for hand grasping in the brain changes according to the context that the hand grasping action is embedded. Participants were shown different video clips in which one of two grasping actions (precision or whole-hand) was presented in one of three context conditions (no context, drinking or cleaning). One of two sets of instructions was given to participants: (1) to simply watch the video clip or, (2) to pay attention to the objects in the display, the grip used and the intention behind the grasping action. The fMRI data showed increased activation in the right inferior frontal cortex, an area associated with the MNS, when scenes in which intention could be inferred were watched. If the MNS did not support the inference of intention then similar activation would have been observed when watching the grasping actions in any of the three contexts. Iacoboni et al. (2005) suggested that, "there are sets of neurons in human inferior frontal cortex that specifically code the ‘why’ of the action and respond differently to different intentions" (p. 533).

1.1.3 Ideomotor Theory: How Perception and Motor Action are Related

James claimed that “every mental representation of a movement awakens to some degree the actual movement which is its objects” (1890, p. 526). This statement reflects the underlying basis of ideomotor theory which stresses the role of internal, volitional causes of action. Actions are thought to arise as a consequence of the will. What this means is that individuals strive to reach particular goals and they contemplate how they can be achieved.
While James (1890) has been traditionally associated with ideomotor theory, it was Lotze (1852) who first introduced the idea that the relationship between action and their mental representations are bi-directional allowing representations to directly produce action. He outlined two conditions which need to be met in order for an individual to carry out voluntary actions. First, the idea or mental image, of the action that one wishes to perform, must exist. Second, any idea or mental image that counters that action must not exist. If these conditions are met then the mental image can proceed in guiding the appropriate movements to make the intended action happen. Some forty years later, James expressed his own ideas of how actions are prompted and guided through internally generated thoughts and intentions in what he described as the ideomotor principle of voluntary action.

The beauty of ideomotor theory, as it relates to our understanding of social interaction, is how it can be extended to account for actions that are induced as a result of perceiving events external to ourselves. Greenwald (1970), a cognitive psychologist, remarked that if imagining an action and its outcome can prompt and initiate that action then could that same action not be induced while perceiving it? He presented participants with visual and auditory letter stimuli and instructed them to respond by either verbally naming or writing it. According to Greenwald, “if images of feedback do mediate voluntary responding, then one should be able to demonstrate this in an RT procedure” (p. 20) and this is exactly what he showed. Response times (RT) were shorter when the image of the stimulus modality and response type corresponded, which supports the idea that perception of events will prompt the production of similar events. This idea that the perception of action external to us can have an influence over our own actions extends to actions that are performed by other people (e.g., Chartrand & Bargh, 1999; Lakin & Chartrand, 2003). Therefore it seems that
watching another person act results in the activation of the same representational structures that govern one’s own planning and control of these actions (Knoblich & Jordan, 2002).

As a final point, ideomotor theory puts forth that when an action is carried out frequently enough a pattern of expected results is established and captured in ‘associations’. A representation coding the perceived outcome of a particular action, on both the body and the environment, will become associated with a representation coding the actual movements that the action entails. Such an association would allow the observer to form certain expectations with respect to a given action, a sort of predictive function (forward computation) (Prinz et al., 2008). Anticipatory representations of the intended and expected effects of a particular action which not only activate when we execute it but also when another person executes it would be especially valuable for joint action. This would give one the ability to predict another person’s next action which in turn would facilitate successful social interaction.

1.2 Let’s Share this World Together

1.2.1 Joint Action and Co-Representation Defined

The bulk of empirical research examining human performance in goal-directed tasks tends to be based on studies in an environment where participants are isolated from others. Rarely, however, do we engage in activities that do not involve interacting with another person(s). Insight into what may be necessary to engage in coordinated, or joint, activities can be drawn from research in language, an area where joint action has been extensively investigated. Take a moment to reflect on having a conversation with a close friend and appreciate what each of you needs to invest for its successful outcome. First, the two of you
had to coordinate the *content* of your conversation and the *process* by which your conversation moved forward (Clark, 1996). If you wanted to talk about tomorrow’s weather forecast in order to prepare for the possibility of rain but your friend starts to talk about the current weather conditions, in say another country, then the conversation has no common ground. Obtaining the desired information is impossible. Furthermore, should your friend choose to dominate the conversation without giving you the opportunity to speak then your conversation will soon stagnate. To effectively engage in such joint activities, participants have to make assumptions about their shared information or common ground which includes mutual knowledge, mutual beliefs and mutual assumptions (Clark & Marshall, 1981).

Verbal communication is a simple and direct way of exchanging information. There are, however, circumstances in which this means of transferring information is not always available or effective. For instance, in basketball, a player is open and they do not want to draw attention to themselves by yelling for the ball. Instead, they gesture with the hand they wish to receive the ball with to their teammate who has the ball. To ensure the smooth coordination of actions between these two individuals, such that the outcome in joint action is successful, will depend on the ability to do three things (Sebanz et al., 2006a). First, it requires the two players to share representations of the objects (e.g., basketball) and events (e.g., position of other players) involved in the interaction; what the other person perceives has to be recognized. Second, it requires the pair to predict what the other will do. If the shared representations, which encompass both the action and the goal (pass and score), formed by these two players are similar, they should understand and predict the outcome of both their own and the other’s actions. Finally, it requires the two players to integrate these predicted actions with the consequences of their own action. Under these circumstances, the
open player may need to ‘read’ the teammate’s (the one with the ball) movements in order to recognize that they will make a fake but then lob the ball to their receiving hand. Concurrently, the passer needs to recognize that the open player will take a step toward the hoop prior to the anticipated pass in order to score; thus the pass will have to go ahead of the open player.

There is no denying that our success as a species can be attributed in large part to our remarkable ability to engage in joint action (Tomasello et al., 2005). As humans, we cannot help but tune our perceptions, decisions and behaviours towards others whom we share beliefs, intentions and common goals with (Bekkering et al., 2008). What makes joint action such an exciting phenomenon to study is the question of how two autonomous neural systems are bridged to allow for effective and efficient interaction on a mutual task. For the purpose of this dissertation, the working definition for joint action will be “any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment” (Sebanz et al., 2006a, p. 70).

1.2.2 Gathering Information to Conform One’s Behaviour with Another’s

How do we “tune into” another person’s actions and intentions during social interactions? Have you ever found yourself stepping in almost perfect synchrony with the person walking in front of you without ever realizing that you changed your walking pattern in the first place? Or wondered how you came to the conclusion that someone was crying because they were sad without having to ask the person what was wrong? According to Sebanz et al. (2005a), “the tendency to pick up social information and unintentionally adjust one’s behaviour to others’ manifests itself in two ways” (p. 1234): (1) coordination, and (2)
co-representation (or shared representation\(^2\)). The unintentional synchronization of leg movements while walking is an example of ‘coordination’ (e.g., Zivotofsky & Hausdorff, 2007). The ability to share another person’s mental representation allows us to infer, why someone is displaying a particular emotion (crying), exemplifies co-representation.

Ideomotor theory offers an explanation for how an individual is able to share another’s representation of a goal-directed action. As was described earlier, the theory proposes that when we perceive or imagine events produced by another person, this activates similar representational structures that preside over our own planning and control of these actions (Greenwald, 1970; James, 1890) which leads to an increased propensity to reproduce what we observe, unintentionally. This is evidenced in studies that have examined the tendency to inadvertently adopt another’s behaviours, postures and mannerisms. For example, it has been found that people are unaware that they are mimicking another’s accent (e.g., Giles & Powesland, 1975); speech rate (e.g., Cappella & Panpalp, 1981); facial expressions (e.g., Dimberg et al., 2000); and posture (e.g., Chartrand & Bargh, 1999).

Behavioural studies have demonstrated that the perception of another person’s actions can automatically activate a motor representation. For example, motor priming is the effect where the observation of another person’s movements facilitates executing a similar motor response oneself. It offers evidence for shared representation when we watch an action and produce that same action ourselves. Brass et al. (2001) showed that response times (RTs) to initiate a finger movement (e.g. index finger) were significantly slower after the visual presentation of a different finger movement (e.g., middle finger) compared to the same finger.

\(^2\) Emotions and beliefs can make up the representational content of shared representations but for the purpose of this dissertation, the representational content will only consist of actions and intention.
What has been presented thus far is evidence that there are representational structures that guide the planning and control of action we wish to execute. When watching another person act, the same representational structures that regulate our performance of that same action are activated. In order for the preceding to take place one needs to be able to see some portion of the action that is being observed, if not the entire sequence of actions (see Umiltà et al., 2001). Only recently have researchers taken a keen interest in exploring the cognitive and neural mechanisms involved in joint activity (Sebanz et al., 2003a). In an experiment that has inspired a whole line of research investigating task sharing, Sebanz and colleagues investigated whether individuals represent the actions of another during joint action.

1.2.3 Task Sharing and Co-Representation

Recognizing that we cannot understand joint action by looking at the individual acting in isolation, Sebanz et al. (2003a) set out to examine how action planning is shaped by the actions of another in the context of social interaction. To explore this matter, they needed to design an experiment in which performance on a distributed task could be compared when participants carried out the task alone or with another person. Using a modified version of the Simon task (Simon & Rudell, 1967), they were able to test whether another person’s task interferes with one’s own performance as a consequence of co-representation. In the classical Simon task participants have to respond to non-spatial stimulus features (e.g., colour) by making a left or right key press response; they are instructed to ignore the spatial location of the stimulus. The Simon effect refers to the findings that RTs are faster and more accurate when the stimulus appears on the same side as the required response (corresponding) compared to when it appears on the opposite side (non-corresponding) (Simon, 1969).
order to infer co-representation, Sebanz et al. (2003) distributed the classical Simon task amongst two participants in this new, social version of the task (joint Go/No-Go condition) and compared the performance to when participants performed their half of the task alone (individual Go/No-Go condition). It has been shown that the SE is not typically observed when participants perform the single response Go/No-Go task alone (cf. Callan et al., 1974; Hommel, 1996). It is this pattern of results that allowed Sebanz et al. (2003a) to investigate whether individuals have formed a representation of the co-actor’s task.

Participants completed the Simon task under three different social conditions: solo, group and standard. In the standard condition, participants were required to make binary choice responses based on the colour of a ring (red or green) that appeared on the index finger of a right or left pointing hand. As predicted, responses were faster when the finger pointed in the same direction as the required response (corresponding trial) than when they did not (non-corresponding trial), replicating the robust SE. In the solo condition, two chairs were positioned side-by-side in front of a computer monitor. Participants were assigned to one of two seat positions (left or right) and they completed a Go/No-Go task alone. The Go/No-Go task required participants to make a single key press response to only one of two target stimuli (i.e., respond to the red ring and ignore the green ring). The results showed that the direction of the pointing finger had no influence on RT (no SE observed). In the group condition, participants were paired with a co-actor who responded to the other stimulus colour, which was previously ignored by the participant in the solo condition. The co-actor now sat in the once unoccupied seat. It is important to note that the task was identical to that which was performed in the solo condition. The only difference was that there was now another person responding to their own distinct stimulus feature. Two potential outcomes
were possible: (1) participants would perform as they would if they were alone (no SE observed) (2) participants would treat the shared task as a whole and represent their partner’s actions (SE observed). The results showed that RTs were faster on corresponding than non-corresponding trials (SE observed). Sebanz et al. proposed that this social Simon effect (SSE) emerged because when participants performed complementary parts of the task, they integrated their response as well as that of their co-actor in a shared representation. Sebanz et al. (2003a) went on to show that the mere presence of another person cannot give rise to the SSE; they need to be involved in the task.

In a subsequent paper, Sebanz et al. (2005a) examined whether co-representation occurs when two individuals perform different tasks alongside each other. One participant was instructed to respond selectively to one of two stimulus colours while another was instructed to respond to the spatial direction of a pointing hand. By assigning each participant their own unique task (colour vs. direction), they were able to investigate whether individuals form shared representation when interpersonal coordination is not necessary. Once more, the SSE was observed in a social setting offering further support for the argument that one cannot help but represent someone else’s task, it is ‘quasi-automatic’, even if this interferes with one’s own action planning and performance (Sebanz et al., 2006a).

Studies using neurophysiological and brain imaging techniques have explored the processes of control at the planning level and isolated some of the neural correlates associated with task sharing, respectively. Using event-related fMRI, changes in brain activity as a function of social condition (solo, group) was assessed with a specific focus on comparing go trials (Sebanz et al., 2007). The rationale for this was that in these two conditions, the sensory input was the equivalent in that the participant responded to stimuli
while the co-actor did not respond; therefore any modulations in brain activity would reflect differences in cognitive and neural processes according to social context in which the task was performed. Participants were placed in the scanner and completed the typical Go/No-Go task in both the solo and group conditions. In the group condition, participants completed the task together with a confederate who sat beside the scanner; the responses of the confederate could be seen by participants. In the solo condition, participants performed the same task while the confederate simply rested their finger on the response device. Activation differences were anticipated in the ventral medial frontal cortex (MFC) and dorsal anterior cingulate cortex (ACC) when performing the same Go/No-Go task in the two different task conditions since these areas have been implicated in action control and monitoring, self-reflection as well as inferences made about others’ thoughts (see Amodio & Frith, 2006, for a review). Increased activation in the ventral MFC was observed when performing the task in the joint condition compared to the solo condition while increased activity in the ACC was identified on non-corresponding trials in the joint condition. Sebanz et al. put forth that these findings support their argument that social context has an influence on stimulus processing.

Lastly, Sebanz et al. (2006b) measured event related potentials (ERPs) to show that task sharing is also affected on no-go trials. The P300 wave has been linked with inhibitory events and peaks between 300 and 600 ms on no-go trials over fronto-central regions (Pfefferbaum et al., 1986; Falkenstein et al., 1995); this augmented P3 has been described as a No-Go P3 component which differs from a Go P3 component which is maximum over centro-parietal regions. The No-Go P3 effect has been interpreted as an electrophysiological

---

3 Typically, in the solo condition, participants complete the Go/No-Go task alone (Sebanz et al., 2003a, 2005a) but in this particular study, the co-actor was present during the “solo” condition and simply rested their finger on their response key.
signature of response inhibition (Kiefer et al., 1998; Roberts et al. 1994).

Electrophysiological studies investigating the modulation of the P3 component in Go/No-Go tasks have identified larger amplitudes at frontal sites on compared to go trials (Eimer, 1993; Kopp et al., 1996). These modulations have been generally considered to be an inhibitory mechanism (Bokura et al., 2001). Sebanz and colleagues hypothesized that if a shared representation was formed in the group condition then it should be activated on no-go trials and participants would have to inhibit more than in the solo condition. This was confirmed in their results where the No-Go P3 amplitude was larger in the group condition, suggesting that there was greater response inhibition on no-go trials because the co-actor’s response alternative was co-represented (also see Tsai et al., 2006).

1.3  What are the Prerequisites for Co-Representation?

1.3.1  Co-Representation and the Biological Agent

Shared representations of task requirements are formed when individuals interact with biological agents. The next question we ask is, does co-representation occur when task sharing with a non-biological agent? Tsai and Brass (2007) had participants perform the same Go/No-Go task on their own (solo), with another biological agent (group, human hand) or with a non-biological agent (group, wooden hand). In the group conditions, participants did not interact with a co-actor but rather a video of either an appropriately sized wooden-hand or a real-hand⁴ was presented on a screen that was positioned next to their hand. The wooden-hand was identical to the real-hand with respect to shape and colour; they differed

⁴ Tsai described the stimuli as a ‘real-hand’ but it was actually a computer generated image and was not an image of a genuine human hand.
only in hand type. Under the interactive context, participants responded to either a red or green stimulus with one response key and the videotaped hand was “assigned” to respond to the other color stimulus. The video shown to participants was either dynamic (perceivable movements) or static (image). The SSE was only observed when participants completed the Go/No-Go task with another *dynamic* biological agent. What makes these finding interesting is that they show that co-representation can occur outside the realm of the real-world. Tsai and Brass (2007) reasoned that the SSE was absent when participants completed the task with a non-biological agent because the human co-representation system is biologically tuned. Various other studies have also demonstrated that processes involved in co-representation are not activated when actions are performed by non-biological agents (e.g., a robot; Ramnani & Miall, 2004; Tsai et al., 2008). However, a more recent study by Müller et al. (2011) has shown that co-representation can be influenced by observing a non-biological agent behaving in a human-like manner. If given the opportunity to watch a video in which a “vivid” image could be formed of the non-biological agent (e.g., Pinocchio) then the wooden hand along which the participant performed the task could be perceived as belonging to an intentional agent. They observed a SSE when participants had watched the video before interacting with a wooden hand; the effect was noticeably absent if the video had not been watch at all. Müller et al. concluded that the human co-representation system is not just biologically tuned and that these processes can activate when interacting with a non-biological agent.
1.3.2 Is Physical Presence Required or is Belief Enough?

When participants perform the Go/No-Go task alongside an individual whose role is to simply sit passively during the task, the SSE does not arise (see Sebanz et al., 2003a, Experiment 2). Co-representation means that a representation of another individual’s task has been formed. The mere presence of another person would not afford a shared representation to be formed because they are not engaged in the task. On trials in which the finger points to the other person, a representation would not be activated and in turn one’s own action planning would not be disrupted; this finding seems counter what has been described as social facilitation. Although the SE was absent when the co-actor sat passively next to the participant, it reappeared when the co-actor performed the complementary part of the task which supports the context-specific ideomotor explanation. Remarks such as, “performance was influenced by knowledge about the other’s task even when the other’s actions could not be observed at all” (Sebanz et al., 2005a, p. 1243) imply that as long as the specific relationship between a particular stimulus and response are identified to the actors, co-representation transpires. There is also the consideration of how the observation of another person’s actions can modify one’s own actions (ideomotor theory) due to the activation of representation of observed actions in the motor system of the observer.

Is it enough to believe that you are sharing a task with another person for co-representation to occur? Or do you need to observe the actions of the person you are task sharing with? This matter of “seeing vs. believing” was addressed by Welsh et al. (2007). Participants were paired and performed the social Simon task with a confederate who either

---

5 Social facilitation is the tendency for performance to alter, in a positive way, on a task when other people are present (see Zajonc, 1965). The term social inhibition tends to refer to the detrimental effect on performance when an audience is present.
completed the task alongside them or in an adjacent room on a networked computer. Unbeknownst to the participant, the confederate initiated a computer program that gave the impression that this was indeed the case. Under these latter circumstances, the co-actor is not physically present but there is the belief that they are still partaking in the task, just in another room. Despite having this impression, the SE was only observed when the confederate performed the task alongside participants. These results reveal that co-representation only takes place when the actions of another person can be observed (cf., Tsai et al., 2008).

1.3.3 The Impact of Positive and Negative Relationships on Co-Representation

Converting the traditional Simon task into a ‘social’ task has allowed researchers to show that individuals tend to integrate in a shared representation their and other’s action alternatives. The term ‘social’ is used in the context of social action, which refers to the interactions between individuals. Hommel et al. (2009) has further developed our understanding of how joint action shapes cognitive processes by examining how social relations can modulate the SSE (Hommel et al., 2009). They examined how the perceived relationship one has with the co-actor can either facilitate co-representation or hamper it. To this end, participants were introduced to their partner and asked to complete the social Simon task. The confederate that participants were paired with were instructed to behave in either a friendly and supportive (“nice”) manner or in a strict and callous (“intimidating”) manner. The “nice” confederate sat alongside the participant, engaged in polite behaviour and was very composed and supportive. The “intimidating” confederate also sat alongside the participant while performing the complementary part of the task stared harshly at the

---

6 Social relation refers to how two (or more) people relate or associate with each other.  
7 The confederate made comments such as, “You are doing a good job.”
participant’s response hand and uttered nasty comments. At the end of the experiment, participants were questioned about how they felt during the testing session. Those who partnered with the negative confederate felt “insecure and irritated” while those who interacted with the positive confederate expressed “pleasant feelings only” (p. 3). The results showed that the SSE was restricted to the condition in which participants interacted with the “nice”, or positive, confederate. In contrast, the SSE was absent when the co-actor was competitive and hostile. These findings present an interesting quandary because the claim has been made that task sharing activates the processes of co-representation, perhaps even quasi-automatically (Sebanz et al., 2006a). This does not seem to be the case when the social relationship is negative. Hommel et al. (2009) thus concluded that social relations can change the way that individuals co-represent in a joint task.

1.3.4 Forming a Shared Representation of Symbolic Information

In efforts to extend the research on joint action that has investigated task sharing, Atmaca et al. (2008) explored the limits of co-representation using the *spatial numerical association of response codes* (SNARC) paradigm. When participants are asked to indicate if a digit is odd or even, responses were faster to large numbers with right responses and faster to small numbers with left responses. According to Dehaene (1997), individuals represent numbers along a mental number line with the small numbers (1, 2...) proceeding from the left to the right as those numbers get larger (8, 9...). The symbolic information (e.g., numbers themselves) presented in this task can act as a spatial cue much like the pointing finger did in Sebanz et al.’s (2003a) original joint action experiment. Atmaca et al. reasoned that this

---

8 The confederate made comments such as, “You have to respond quicker”.
“raises the possibility that even the processing of symbolic information makes use of the close perception-links embodied in the mirror system” (p. 3). By comparing the size of the SNARC effect in a solo and a joint condition, it could be determined whether stimuli, for which spatial information is derived during cognitive processing, could elicit co-representation. In the solo condition, participants made parity judgments to Arabic digits ranging from 2-9, responding with a single response to either odd or not even, or vice versa; these numbers appeared at the centre of a display. In the group condition, two participants were sitting side-by-side. In the standard condition, single participants responded to both odd and even numbers making binary choice responses. The SNARC effect was observed in both the group and standard conditions but was noticeably absent in the solo condition. Number magnitude affected RTs such that left responses were faster when small number were presented than when large number were presented. The different RT patterns observed in the solo and group condition were taken as evidence that co-representation can also occur when responding to stimuli where the task-irrelevant feature conveyed cognitively derived spatial information. Moreover, Atmaca et al. demonstrated that numerical magnitude is mapped onto a mental number representation that is spatially oriented from left to right on a sort of number line even in a social context.

1.4 Aims of the Current Studies

My goal in conducting the studies presented in this dissertation was to identify necessary preconditions under which shared representations are formed and to test alternative explanations to the co-representation account as proposed by the task sharing literature (Sebanz et al., 2003a, 2005, 2006). For this purpose, we used the so-called ‘social’ Simon
paradigm in which two individuals share a Simon task (Sebanz et al., 2003a) to further investigate the nature of co-representation.

Our first objective was to confirm that the SSE would not be observed in a joint-action condition in which both participants had a common goal. To address this matter, participants responded to the same stimulus-response (S-R) alternative. Under these conditions, a shared representation, if formed, would not be expected to have any influence on performance. As anticipated, performance in a joint-action task showed no social Simon effect.

Our second objective was to consider how competition impacts the activation of shared representations. When responding to the same S-R alternative, it is possible that a competitive context was inadvertently induced. Studies examining performance in a competitive joint action task have provided mixed results (see de Bruijn et al., 2008 and Ruys & Aarts, 2010). To determine whether a non-competitive task is a necessary precondition for a shared representation to be formed we examined performance in a joint-action condition where participants were explicitly instructed to respond faster than their opponent. We showed a SSE under the competitive context which suggests that individuals co-represent even when it is disadvantageous with respect to the task goal.

Our third objective was to explore whether the joint SE is primarily driven by spatial response coding or co-representation. There has been suggestion that when engaged in a joint action task, the co-actor may be used as a spatial reference point to code responses along the horizontal dimension which elicits the SSE (see Guagnano et al., 2010 and Welsh, 2009). To further test this alternative explanation for the joint SE, we manipulated the spatial position of participants relative to the co-actor by changing the seating arrangement from one joint
action task to the next. Our results did not support the notion the joint SE is based on spatial
coding of personal location, however, we questioned if our manipulation was too intrusive
and as a consequence spatial re-coding was abandoned.

Our fourth objective was motivated by the response discrimination hypothesis (RDH)
which explains variations of the SE (Ansorge & Wühr, 2004, 2009). The RDH puts forth that
when a task affords the discrimination of response alternatives according to spatial features
(e.g., left-right) which are then represented in working memory (WM), the SE can be
elicted. We felt that the alternative spatial coding account deserved further attention and the
RDH provided us with a framework to explore the possibility that spatially discriminated
responses represented in working memory (WM) may be responsible for eliciting the joint
SE observed in task sharing studies. It was shown that a SE can be observed in a Go/No-Go
task when it is preceded by a 2-choice (TC) task (Ansorge & Wühr, 2004). We examined
whether a SE could be elicited in a Go/No-Go task when it was preceded by a Go/No-Go
task where the opposite stimulus colour was responded to using the opposite response key, a
JA task, and/or a TC task. We also included a sequence of tasks in which a JA task was
followed by a TC task and finished with JA task. Our results showed a SE in a Go/No-Go
task when it was preceded by a TC task, as predicted by the RDH. This was not the case
when the Go/No-Go task was preceded by a JA task or a Go/No-Go task in which the
opposite response key was used to respond to the opposite stimulus colour. This experiment
was not without complication as we were not able to replicate the SSE in any of our JA tasks,
though the trend toward the SE was in the right direction in one of the sequence groups (i.e.,
faster RT on corresponding compared to non-corresponding trials).
Our fifth objective was twofold: (1) to identify whether the social nature of the cueing stimuli (i.e., pointing finger) used by Sebanz et al. (2003a) induces a larger SSE than non-social stimuli (i.e., coloured asterisk) and (2) to assess how cognitive processes differ, if at all, when interacting with another person on a collaborative task versus performing alongside another person on two independent tasks. We first conducted a replication of Sebanz et al.'s (2003a) original study using finger pointing stimuli as opposed to the simple stimuli (e.g., coloured asterisks) in our previous experiments and found a SSE. Using the same social cueing stimuli, we examined whether the joint SE could be observed when participants performed independent tasks alongside each other. When a task afforded the discrimination of response alternatives according to their spatial position, the SE was observed; this was not the case when there was only one response alternative. We also recorded electroencephalography (EEG) to evaluate specific event-related potentials (Go P3 and No-Go P3 components) associated with stimulus evaluation (Kok, 2001) and response inhibition (Falkenstein et al., 2002) to identify any differences, or similarities, in the processes of action planning and action control when acting together in a complementary versus a non-complementary (independent) task. Our ERP data did not corroborate previous work showing increased inhibition when engaged in a group Go/No-Go task as opposed to a solo Go/No-Go task which was interpreted as evidence for co-representation (Sebanz et al., 2006b). In fact, we showed that there was increased action suppression in the solo condition compared to the group condition. We also observed a similar pattern of ERP results when participants performed two independent tasks and assigned alternative responses. In contrast, when participants performed two independent tasks using the same response key, there was no apparent difference between the solo and group conditions.
Our final objective was to examine whether co-representation occurs in a task that provides participants with advanced information about the upcoming target location. To test this, we used the response precuing paradigm developed by Miller (1982) which was adapted from Rosenbaum’s (1980, 1982) movement precuing paradigm. The occurrence of a social response precuing effect would provide evidence that another person’s task rules is still represented even when the required response is known in advance. Using a response precuing task, we examined performance when participants have two alternative responses at their disposal in the joint condition as well as advance information about the required response. The four-choice task was performed alone, split between two participants and with one hand only (making it a 2-choice task) alone. The results from this study did not support an account of co-representation when participants engage in a response precuing task. Instead we observed behaviour which could be described as being *individualistic* in nature such that participants focused solely on their part of the task, ignoring the co-actor’s task.
2 Chapter: Study 1 - Influence of Stimulus-Response Assignment on the Joint Simon Effect

2.1 Introduction

The likelihood that you will engage in some sort of interaction with another individual during your daily routine is almost inevitable. It may be as effortless as greeting your co-worker in the office or asking a stranger for directions. On the other hand, moving a piece of heavy furniture with a friend or passing a soccer ball to your teammate presents the challenge of coordinating actions across two (or more) distinct nervous systems in such a way that a common goal is met successfully. Neither one of the preceding two tasks could be carried out by simply imitating the movements of one’s co-actor. However, that is not to say that some aspects of the movement will not be replicated (e.g., equal amounts of force generated by each person to lift the object). Sebanz and colleagues (2006a) have proposed that such goal-directed tasks require complementary responses that are rooted in (1) shared representations of the objects and events, (2) the prediction of actions, and (3) the capacity to incorporate the predicted action of another with one’s own. All 3 factors are thought to contribute to effective joint action. Interest in the nature of shared representations, in particular, has prompted researchers to investigate how performance in a task changes as a function of whether it is carried out alone or together with a partner.

A recent series of studies examining joint action has demonstrated that when two individuals are paired together as partners in a task, such that each is responsible for one part of the task, each person represents not only his or her own action, but also that of the partner (Sebanz et al. 2003a; 2005b; 2006b). Sebanz et al. (2003a) presented one of the first studies
to support this “joint-action” effect using a modified variant of a spatial correspondence task (the Simon effect). In a standard Simon effect task, participants are instructed to make a left or right key press response based on the feature (e.g., colour) of a stimulus, which can appear on the left or right side of fixation. Even though stimulus location is irrelevant to the task, participants react faster and more accurately to stimuli that appear on the same side as the appropriate response (corresponding) than when they appear on the opposite side (non-corresponding) (Simon, 1969); this is described as the Simon effect. Sebanz and colleagues (2003a) used this Simon effect paradigm under a go/no-go protocol in which participants were presented with photographs of a pointing hand with a ring on the index finger. The index finger pointed either to the left, right, or straight ahead and the ring was coloured either red or green. Participants were instructed to respond to one of the colours of the ring (go trial) and to ignore the other (no-go trial). Thus, the colour of the ring was the task-relevant stimulus dimension for the task while the direction in which the finger pointed was the irrelevant dimension.

Sebanz et al. (2003a) found that when participants completed the task individually (alone), the direction of the pointing finger had no influence on response times (no correspondence effect). However, when participants were paired with a partner who was responsible for responding to the other ring colour, response times were faster on corresponding versus non-corresponding trials (a correspondence effect). What is important to recognize is that in the latter condition, participants were performing the same task that they had previously completed on their own, and that the response of the partner had no bearing on the task. Nevertheless, response performance was affected. Sebanz and colleagues proposed that these findings demonstrated that participants formed a
representation of the task as a whole even though they were only responsible for one part of it. These joint-action effects have been replicated in other behavioural (Sebanz et al. 2005a; 2005b; 2006b; Tsai and Brass, 2007; Welsh et al., 2007), electrophysiological (Sebanz et al., 2006b; Tsai et al., 2006), and neuroimaging studies (Sebanz et al., 2007).

The basis for the joint-action correspondence effect, as proposed by Sebanz and colleagues is that one represents the response alternative of the other person during the joint-action task. In the present study, we aimed to verify that the correspondence effect would not arise under a joint-action condition in which a person would not be expected to form a shared representation of another’s action (in other words, a condition in which the formation of a shared representation would be expected to offer no performance advantage). To this end, we examined performance in a condition in which both participants responded to the same stimulus-response alternative in a joint-action task. We reasoned that because participants are concurrently performing the same task with the same response alternatives, a shared representation, even if formed, would not be expected to influence responding. Therefore, no correspondence effect was expected in such a condition. In contrast, when participants perform a complementary task in which they respond to different stimulus-response alternatives, a correspondence effect was anticipated.

2.2 Methods

2.2.1 Participants

Twelve participants completed the experiment (eight females; mean age = 22.1 years, SD = 2.4 years). All participants were right-handed and all had normal or corrected-to-normal
vision. The study was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent.

### 2.2.2 Apparatus

Testing took place in a room with a computer monitor (ViewSonic G90F 19") set in the middle of a desk. Two chairs were placed side-by-side in front of the monitor. Participants were randomly assigned to one of two seats (left or right); seat position also determined response hand (i.e., left seat: left hand, right seat: right hand). Participants put their index finger on a single response key placed on the same side as the response hand (e.g., for a left hand response, the response key was to the left of the participant’s midline). A second response key was placed on the table after it was revealed to participants that the following two tasks included a partner. Participants kept their inactive hand on their lap. To ensure that participants did not receive any auditory feedback, they wore ear-plugs and ear muffs to eliminate the sound of the key presses. Visual feedback of the hands was also eliminated by hiding the response hand with a box that covered the entire area in front of the monitor.

### 2.2.3 Stimuli

All trials started with a white fixation cross presented at the centre of the computer monitor against a black background. It appeared for a randomly varied duration of 1000, 1400 or 1800 ms. The target was either a blue or orange asterisk (approximately 2 deg or 2 cm diameter) which was presented randomly to either the left or right of fixation (approximately 7 deg or 7 cm). The target remained on the screen for 1250 ms irrespective of whether a
response was made by one of the two participants. This allowed us to record the RTs of both participants. The inter-trial interval was 2000 ms.

2.2.4 Procedures

The entire experiment consisted of four different conditions. Instructions were presented both verbally by the experimenter and visually on the monitor at the beginning of each condition. In the Individual Go/No-Go condition (IGNG), participants sat to the right or left of the display with an empty chair beside them. Participants were instructed to respond to one of the two target colours and to ignore the other one. In both the Joint Go/No-Go Different-Alternative (JD) and Joint Go/No-Go Same-Alternative (JS) conditions, participants remained in the same seat and their partner occupied the empty chair beside them. As in the IGNG condition, participants responded to the same colour target while their partner responded to the other colour (JD condition) or their partner responded to the same colour target (JS condition). In the 2-choice (TC) condition, the partner left the testing room and their chair was removed; the participant then moved their chair to centre themselves in front of the monitor. Participants were instructed to place the index finger of their inactive hand on the second key and to respond to the previously ignored colour with it. Each condition consisted of one block of 80 trials, in which participants completed ten practice trials at the beginning with the exception of the two joint conditions in which no further practice was carried out. Participants had a short break after the first 40 trials in each condition. The testing session lasted approximately one hour, which included preparation and breaks.

Participants always carried out the IGNG condition first. Upon completion, participants were told that another participant would be joining them for the next two
conditions. However, unbeknownst to participants, this second participant was a confederate (another experimenter). A confederate was used for ease of scheduling participants. Participants were not aware that their partner was a confederate. The confederate acted simply as a second task participant, and neither the actual participant nor the confederate verbally communicated with one another. The order of the next two conditions (JD vs. JS) was counter-balanced across pairs of participants. In the JD condition, participants were instructed to respond to one color (e.g., blue) and the confederate was instructed to respond to the other color (e.g., orange). In the JS task, both the participant and the confederate were instructed to respond to one color only (e.g., blue) and to ignore the other color (e.g., orange). It is important to note that participants responded to the same colour with the same hand in all conditions to avoid the need for re-mapping. The 2-choice condition was always the last condition that participants completed, to prevent potential carry-over effects from a 2-choice to a Go/No-Go condition (Ansorge and Wühr 2004; 2009). Participants were informed to respond as quickly and as accurately as possible since response time was the measure of interest.

2.3 Results

For the data analysis, trials were excluded if the wrong key was pressed or if no response was detected. The data for each condition were sorted according to trial type (stimulus colour and location) and any response times (RT) that were below 100 ms or above 1000 ms were also eliminated from further analysis. The mean error rate for the IGNG condition was 0.2%, and 4.5% in the TC condition. For the joint tasks, it was 0.8% in the JD condition and 0.2% in the JS condition.
Figure 2.1 shows the mean RTs for the four task conditions. First, we compared the conditions in which participants completed the RT task on their own, using a 2 Individual Task (IGNG, TC) X 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA. To ensure that the two task condition means were derived from a similar number of trials, the means for the TC condition were derived only from the same hand that was also used by participants in the IGNG, JD, and JS task conditions.

Figure 2.1  Mean RT on corresponding and non-corresponding trials for the IGNG, TC, JD and JS task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 38 ms and 37 ms for the IGNG task; 24 ms and 26 ms for the TC task; 27 ms and 27 ms for the JD condition; and 28 ms and 27 ms for the JS condition.

The analysis revealed only a significant interaction \( F(1, 11) = 8.574, p = .014 \).

Neither the main effect for Task \( F(1, 11) = 2.655, p > .1 \) nor Correspondence \( F(1, 11) = 4.273, p > .063 \) reached statistical significance. Post-hoc analysis (Newman-Keuls test, \( p < \)
.05) of the interaction revealed significantly faster mean RTs on corresponding than on non-corresponding trials (i.e., a Simon effect) when participants responded to both stimulus-response (S-R) alternatives (TC condition). When participants responded only to one S-R alternative, and performed the task alone (IGNG), RTs on corresponding trials were not significantly different from non-corresponding trials.

Next, we compared the two Joint Task conditions when participants performed the RT task together, using a 2 Joint Task (JD, JS) X 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA. Analysis again revealed only a significant interaction [\(F(1, 11) = 9.427, p = .011\)]. The main effects for Task [\(F(1, 11) = 0.563, p > .47\)] and Correspondence [\(F(1, 11) = 1.03, p > .33\)] were not significant. Post-hoc analysis (Newman-Keuls test, \(p < .05\)) of the interaction revealed that when each participant was responding to their respective stimulus-response alternative (JD), RTs were faster on corresponding trials than on non-corresponding trials. This is consistent with Sebanz et al.’s (2003; 2005a; 2005b; 2006) findings. In contrast, when participants performed the task together, but responded to the same S-R alternative (JS), the spatial correspondence between the stimulus and response did not influence RTs.

### 2.4 Discussion

The present results provide further support for action co-representation, in line with Sebanz and colleagues’ (2003a; 2005a; 2006b) findings. The absence of a correspondence effect in the IGNG condition shows that performing one part of a two-part task individually does not typically yield a correspondence effect because there is no action alternative to represent (i.e., another person’s response is not at one’s disposal). In contrast, when performing a
complementary task with a partner, the potential for representing the other person’s action alternative exists, resulting in the joint-correspondence effect. Sebanz et al. (2003a) have shown that the mere presence of another person that simply watches the participant perform the Go/No-Go task alone does not elicit the joint-correspondence effect. Sebanz et al. (2005a) have made the case that shared action representations are formed based on the knowledge of a partner’s task instructions and not just as a consequence of simply observing another’s actions. By designing a condition in which both participants had a common goal (i.e., both respond to the same S-R alternative), we hypothesized that a shared representation may not be formed because both participants would be completing the same task alternatives. Our present results show that when a partner is jointly engaged in the task, but represents the same action alternative (thus, the representation of the other’s action should be no different than one’s own), a joint-correspondence effect is also not expressed. This is in contrast to the condition in which paired participants were jointly responding to different stimulus-response alternatives. In this situation, a correspondence effect was found, which further suggests that joint action depends on shared representations (Knoblich & Sebanz, 2006). Thus, it appears that the joint-action correspondence effect (Sebanz et al., 2003a; 2005b; 2006b) specifically requires that not only must both participants engage in the task (Sebanz et al., 2003a; Tsai & Brass, 2007), but they must also respond to different action alternatives.

---

9 Guagnano et al. (2010) have recently shown that a similar spatial correspondence effect may also be obtained in a situation in which two participants simultaneously, but independently, perform non-complementary simple RT tasks. These authors propose that when the participants perform a non-collaborative task, the presence of between-person spatial correspondence effects may be a result of the spatial coding induced by the presence of a second participant. That is, the presence of another person might provide a reference for the spatial coding of one’s own action. Correspondence effects are then thought to arise as a result of this spatial coding, and not necessarily from the shared representation of the other person’s actions.
2.5 Bridging Summary

What we were able to establish in Study 1 is that under a joint-action condition in which one would not need to form a shared representation of their co-actor’s task, no social Simon effect (SSE) would be elicited. In the case that both participants are assigned the same stimulus-response alternative, the activation of shared representations, if formed, would not be expected to result in any facilitation on corresponding trials nor any conflict on non-corresponding trials. Our findings support this hypothesis.

In Study 2, we addressed the possibility that we may have inadvertently created a setting conducive to competition by instructing participants to respond to the same coloured stimulus with their respective responses. Since both participants are contending for the same goal (e.g., blue stimulus) a certain degree of competition may have developed. To address this matter, we examined joint action in a competitive setting to determine if this had an influence on the activation of the processes that produce task co-representation. In contrast to Study 1, participants were explicitly instructed to always try and respond faster than their opponent. Response time feedback was presented at the end of each trial to ensure that a competitive context was maintained. Even though it would be detrimental to form shared representations in a non-cooperative situation, we hypothesized that co-representation would occur since it has been suggested that this process takes place quasi-automatically (Sebanz et al., 2006a).
3 Chapter: Study 2 - Influence of Response Competition on the Social Simon Effect

3.1 Introduction

The mental and motor processes involved in performing a task in an individualistic situation are modified when another person engages in that same task. Consider, for example, playing a musical instrument such as the violin. When playing a solo piece, a musician only takes their own actions into account: when to draw their bow across the strings, how to play a *col legno* as opposed to a *spiccato* stroke, or when to slowdown or pickup their tempo. Introduce another person to the task for the purpose of playing a duet, however, and now that person’s mental and motor processes must be factored in and coordinated with when the, once solo, violinist selects their actions. While it may seem that each person is carrying out individual autonomous actions, there are modifications being made in the planning and control of action when engaging with another person in attempts to achieve a common goal (e.g., playing a duet). While a musician may be playing the same piece of music in both the solo and duet setting, the processes involved under a social context (i.e., duet) are different, even though the actions appear identical (Clark, 1996). In efforts to better understand the abilities necessary to engage in successful joint action, the influence of another person’s action has been examined in a complementary task in which interpersonal coordination was unnecessary (Sebanz et al., 2003a, 2005a, 2005b; Tsai et al., 2006; Welsh et al., 2007). Such studies have specifically investigated what has been described as “shared representations”, as one of several abilities necessary to carry out successful joint action (Sebanz et al., 2006a). A means of examining this particular ability has been to modify the classical Simon task to
identify any performance differences when the task is carried out alone as opposed to with another person.

First described by Simon and Ruddell (1967), the Simon effect (SE) can be observed in reaction time (RT) tasks in which the position of the stimulus and the response vary along a common spatial dimension (e.g., left-right). The Simon task typically consists of a 2-choice task in which participants execute a spatially specified response to a non-spatial feature such as colour. For example, a participant may be instructed to make a left key press response when a green circle is presented and to make a right key press response when a red circle is presented. Stimuli are presented on either the left or right side of the display and participants are informed that stimulus position is completely irrelevant to the task. Based on the aforementioned stimulus-response (S-R) mapping, when a red circle appears on the right side of the display, a right response would be required. On this particular trial, the stimulus and response are spatially corresponding and this has an influence on performance such that RTs are faster and accuracy increases. In contrast, if that same red circle appeared on the left side of the display, based on the explicit instructions, a right response would be required. In this situation, the stimulus and the response do not spatially correspond and this interferes with performance such that responses are slower and less accurate.

At this time, dual-route models are the most widely recognized explanation for the SE (e.g., de Jong et al., 1994; Eimer et al., 1995; Kornblum, 1994; Kornblum et al., 1990; Zhang et al., 1999). These models assume that the SE is caused by the parallel activation of two independent response-selection routes. Processing along the “conditional” (or “intentional”) route is thought to be relatively slow and stimuli are translated according to task instruction. A response is selected according to the relevant stimulus features (e.g., colour) and the S-R
mapping rules. In contrast, the “unconditional” (or “automatic”) route leads to processing of stimuli relatively quickly and activates the response that corresponds to the stimulus position in an automatic manner.

An example of one of the more general of these dual-route models used to account for the SE is the dimensional overlap model (DOM) (Kornblum, 1994; Kornblum et al., 1990). According to the DOM, the SE is generated as a consequence of overlapping properties in the stimulus and response set, in this case spatial dimension which generally varies along the left/right dimension (see Lippa & Adam, 2001; Guiard, 1983 for variations of other spatial dimensions). For instance, when the stimulus appears on the left side of the display, it automatically activates the corresponding property in the response set which also shares the attribute of a left-right dimension; this is irrespective of the fact that stimulus position is irrelevant to the task. What is observed is a facilitation in performance because there is no conflict between the two response codes. In connection with the two parallel routes of response selection, the DOM describes the “unconditional” route as stimulus-driven or strongly automatic. In contrast, the “conditional” route processes the task-relevant stimulus dimension (e.g., colour) to identify the appropriate response which is based on the designated S-R mapping, making it a more controlled pathway. When the activated response codes of these two routes differ then interference arises and performance is hindered because the correct response has to be selected against the incorrect activation along the “unconditional” route.

In a study by Sebanz et al. (2003a), the classical Simon task was set up in such a way that performance of the task alone could be evaluated against that same task being performed with another person. This experimental design allowed them to examine how working jointly
with another person on a complementary task can influence one’s own performance and how that actions of another person are mentally represented. In what was described as the “Joint Go/No-Go” condition, one participant was asked to respond to red rings on an index finger which pointed to the left or right while the other participant (a confederate) was asked to respond to green rings. The direction of the pointing finger provided the irrelevant spatial dimension. Performance in this condition was compared to that when participants carried out the identical Go/No-Go task alone (“Individual Go/No-Go” condition). What was observed was a spatial correspondence effect, the same effect reported in the 2-choice classical Simon task, but in the Joint Go/No-Go condition only. What makes this observation so intriguing is that participants were still performing the same Go/No-Go task as they did in the individual condition yet when another person was introduced to work jointly with them, the participant’s performance changed. These findings have been interpreted as evidence that participants represent the actions of their partner in a functionally equivalent way which leads to the formulation of the task as a whole rather than two separate parts. This was in spite of the fact that the other person’s actions had no bearing on one’s own responsibilities in the task.

Lam and Chua (2010) recently set out to substantiate that the correspondence effect would not be observed in a joint-action condition in which one would not be expected to form a shared representation of another person’s action. In the case that one did form a shared representation then it would offer little advantage to one’s performance in the task. They examined performance in a shared task in which both participants responded to the same S-R alternative. Participants were paired with another person and their task was to respond to the same stimulus feature (e.g., blue asterisks) with one making a left key press
and the other making a right key press response. No *social Simon effect* (SSE) was expected since both participants were concurrently performing the same task with the same response alternatives and even if a shared representation was formed it should not influence responding. Their results showed that responding jointly to the same S-R alternative does not result in a SSE.

One potential issue with Lam and Chua’s (2010) experiment is that when both participants were responding to the same S-R alternative, this may have inadvertently created a setting conducive to competition. Although the setting was competitively neutral in that participants were not explicitly instructed to outperform the other, nor should this have been their intention, it was possible that the task may have implicitly interpreted as competitive in nature. Consequently, participants may have no longer perceived the person sitting next to them as a “partner,” but rather as an “opponent”.

In a competitive setting, an individual, or group, is trying to outperform their opponent(s) and to assess how their performance compares with others during that the same task; ultimately one’s success denotes another’s failure (Deutsch, 1949). This is in contrast to cooperation in which individuals or groups share a common goal and work towards it. Therefore, the central difference between these two concepts is that in competition, one is highly influenced by personal objective whereas in cooperation, one is focused on the common objective (Lewis, 1944). Based on this discrepancy between the objectives of cooperation and competition, in a cooperative setting where participants are completing a task in which they are trying to reach a common goal, one would benefit from incorporating their partner’s actions into their own system and thus forming a shared representation of the task at hand. In contrast, one would predict that when two participants compete with each
other it would be advantageous to disregard their opponent’s response, to avoid the formation of a shared representation and to focus solely on one’s own part of the task.

The impact of competition on the formation of shared representations has recently been considered by behavioural and electrophysiological studies. Hommel et al.’s (2009) work has demonstrated that when a participant was paired with someone who was pleasant and offered positive feedback in a shared task, the SSE emerged. When a participant was paired with someone who was threatening, competitive and made negative comments then a SSE was not observed. These findings imply that in a competitive interpersonal setting, one does not integrate the actions of an opponent into one’s own action system. Factors other than psychological ones have been manipulated to evaluate how competition may influence when shared representation will be activated. For example, Ruys and Aarts (2010) examined performance in a shared task when the goal of the task was either mutual or conflicting (described as “interdependent”), or when the goal of the task was unrelated to that of the co-actor (described as “independent”). Even in a competitive situation, their results suggest that shared representations are formed to the same extent as in a cooperative situation. This conclusion, however, conflicts with those of Hommel and colleagues (2009). de Bruijn et al. (2008) measured both behaviour performance and response inhibition (No-Go P3) in a competitive setting while executing a social speeded choice-reaction task and identified differences in the extent to which one incorporated another person’s actions with their own based on whether they were a successful (fast responders) or unsuccessful (slow responders) competitor. They put forth that hindering the formation of shared representations (or in the case that one has already been formed) contributed to one’s success in the competitive

---

10 Although Sebanz and colleagues (2006a) would argue that individuals cannot help but form shared representations as co-representation is quasi-automatic.
setting. Conversely, those who were more inclined to form shared representation, which in turn interfered with their own action plan, were unsuccessful when competing against others.

In the present experiment, we examined joint action in a competitive setting to determine if this had an influence on the formation of shared representation. We hypothesized that shared representations would be formed in an explicitly competitive context and in turn have an effect on one’s own actions, resulting in the SSE. This premise is based on the ideomotor principle (Greenwald, 1970; James, 1890; Prinz, 1987) which suggests that the perception of another’s action leads to the automatic activation of an internally generated, and anticipatory, representation of that same action within the perceiver. It is this automaticity that may hinder the capacity to ignore the action alternative of another and prevent the generation of a shared representation, a point raised by Sebanz and colleagues (2003a, 2005a).

3.2 Methods

3.2.1 Participants

Twenty-four participants were recruited from the University of British Columbia for this experiment (12 females; mean age = 23.9 years, SD = 3.0 years). All participants, with the exception of two, were right-handed and all had normal or corrected-to-normal vision. All participants gave written consent, and the study was conducted in accordance with the ethical guidelines set out by the University of British Columbia.
3.2.2 Apparatus

Testing took place in a room with a computer monitor (ViewSonic G90F 19 in.) set in the middle of a desk. Two chairs were placed side-by-side in front of the monitor. Participants were randomly assigned to one of two seats (left or right); seat position also determined response hand (i.e., left seat, left hand or right seat, right hand). Participants put their index finger on a single response key placed on the same side as the response hand (e.g., left hand response, response key to the left of participant’s midline). A second response key was placed on the table after it was revealed to participants that the following two tasks included a partner. Participants kept their inactive hand on their lap. To ensure that participants did not receive any auditory feedback, both ear-plugs and ear muffs were worn to eliminate the sound of the key presses. Visual feedback of the hands was also eliminated by hiding the response hand with a box that covered the entire area in front of the monitor.

3.2.3 Stimuli

All trials started with a white fixation cross displayed at the centre of the computer monitor against a black background. It appeared for a randomly varied duration of 1,000, 1,400 or 1,800 ms. The target was either a blue or orange asterisk (approximately 2° or 2 cm diameter) which was presented randomly to either the left or right of fixation (approximately 7° or 7 cm). The target remained on the screen for 1,250 ms irrespective of whether a response was made by one of the two participants. This allowed us to record the RTs of both participants. The inter-trial interval was 2,000 ms.
3.2.4 Procedures

Upon arriving at the experimental session, participants completed an informed consent form and performed in three different testing conditions: Individual Go/No-Go (IGNG), Joint Competitive Go/No-Go (JC) and 2-choice (TC). Confederates often act as the co-actor that participants are paired with in joint action studies (Lam & Chua, 2010; Sebanz et al., 2003, 2005a; Welsh et al., 2007), however, we chose to pair naïve participants together in efforts to create a genuinely competitive experience. Participants were scheduled such that one participant arrived approximately fifteen minutes prior to their opponent to carry out the IGNG condition. Upon completion, the first participant was taken to another room, during which time their opponent was brought into the testing room to carry out the IGNG condition. Note that paired participants responded to a different stimulus feature (e.g., orange or blue) when completing this condition, never the same stimulus feature (e.g., both orange). Once their opponent finished, the first participant was brought back into the testing room and was asked to sit down in the empty chair next to their opponent. In JC condition, both participants completed the same task as they did in the IGNG condition. To establish an explicitly competitive context, participants were instructed to always try and respond faster than their opponent. RT feedback was presented at the end of each trial and was available to both participants in an attempt to maintain a competitive mind-set. Once more, both participants were told to respond as quickly and as accurately as possible to their respective stimuli since RT was the measure of interest in the experiment. The experimenter ensured that each participant was aware of the other’s stimulus-response mapping.

Following the JC condition, the opponent was taken to another room while the first participant carried out the TC condition. In the TC condition, the co-actor’s chair was
removed and the participant then moved their chair to centre themselves in front of the monitor. Participants were instructed to place the index finger of their inactive hand on the second key and to respond to the once ignored colour with it. After completing this part of the experiment, the first participant was debriefed and left the testing session. This process took approximately 10 minutes, after which time their opponent came back into the testing room to also complete the TC condition.

The instructions were presented both verbally by the experimenter and visually on the monitor at the beginning of each condition. Participants always carried out the IGNG condition first, followed by the JC condition and finishing with the TC condition. The reason that the IGNG condition was completed first and the TC condition was always completed last was to prevent potential carryover effects from a TC to an IGNG condition (Ansorge & Wühr, 2004, 2009). Participants were informed to respond as quickly and as accurately as possible since response time was the measure of interest.

3.3 Results

For the data analysis, trials were excluded if the wrong key was pressed or if no response was detected. The data for each condition were sorted according to trial type (stimulus colour and location) and any response times (RT) that was below 100 ms or above 1,000 ms were also eliminated from further analysis. The mean error rates were: IGNG condition, 0.0%; TC condition, 2.1%; JC condition, 1.0%. One participant’s dataset was removed because their error rate was above 15% due to a technical malfunction; their partner’s data were also subsequently excluded. As a result, the analysis was based on the data of 22 instead of 24 participants.
Figure 3.1 shows the mean RTs for the three Task conditions. We first analyzed the two individual task conditions, using a 2 Individual Task (IGNG, TC) X 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA. Analysis revealed significant main effects for Task \([F(1, 21) = 126.99, p < .001]\) and Correspondence \([F(1, 21) = 10.78, p = .004]\). Overall, mean RTs were faster in the IGNG than in the TC task condition and on corresponding trials than on non-corresponding trials. There was no Task X Correspondence interaction \([F < 1]\) which suggested that overall there was a correspondence effect in both the IGNG and TC task conditions. To confirm this, we decided to conduct a simple effects analysis for each of the Individual Task conditions. When participants performed the TC task in which they responded to both S-R alternatives, mean RTs were faster on corresponding than on non-corresponding trials \([F(1, 21) = 4.63, p = .043]\). RTs in the IGNG condition showed a marginal correspondence effect \([F(1, 21) = 4.05, p = .057]\). Although this was contrary to our expectations, small correspondence effects have been observed previously in IGNG conditions (cf. Sebanz et al. 2005a); such findings have pointed to other factors (e.g., carryover effects) that could contribute to possible correspondence effects in IGNG situations (Ansorge & Wühr, 2004, 2009; Shiu & Kornblum, 1999). More importantly for the present results, a larger correspondence effect was observed when participants performed the task together in a competitive context (see Figure 2.1). A one-way repeated measures ANOVA revealed that in the JC condition, mean RTs were significantly faster on corresponding than on non-corresponding trials \([F(1, 21) = 11.326, p = .003]\). This joint-action correspondence effect suggests that even in a competitive context, individuals appear to form a shared representation even when it is disadvantageous with respect to the goal of the task (i.e., outperform your opponent).
Figure 3.1  Mean RT on corresponding and non-corresponding trials for the IGNG, TC, and JC task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 6 ms and 6 ms for the IGNG task; 11 ms and 8 ms for the TC task; and 4 ms and 5 ms for the JC condition.

3.4 Discussion

As discussed earlier, de Bruijn et al. (2008) recently examined the nature of shared representations in a competitive context and how the formation of a shared representation, or lack thereof, impacted performance in a speeded-response paradigm. Their work followed on two event-related potential (ERP) studies that evaluated response inhibition by measuring the “No-Go P3” ERP component. Sebanz et al. (2006b) and Tsai et al. (2006) showed that the amplitude of the No-Go P3 ERP is larger on no-go trials in a Joint Go/No-Go condition compared to an Individual Go/No-Go condition. These results were taken to indicate that a
representation of another person’s action was formed during the joint-action condition and thus required response inhibition when the associated stimulus was presented to ensure that one did not execute the anticipated response. de Bruijn et al. (2008) examined whether response inhibition was also evident in a competitive setting. These authors required participants to respond to the onset of a single letter which also indicated whether both participants responded, neither responded, or only one responded. Participants were aware of their partner’s S-R mapping and that the task was a competitive one in which they were trying to respond faster than their partner.

de Bruijn et al. (2008) categorized participants as either “fast” or ”slow” responders by comparing response times within participant pairings on trials in which both participants responded. Only “slow responders” were found to have significantly larger No-Go P3 amplitude when required to suppress their response while the other participant responded. de Bruijn and colleagues concluded that “slow responders,” or “unsuccessful competitors,” cannot hinder the formation of a representation of the action alternative, thus necessitating the subsequent inhibition of the response. In contrast, “fast responders” were thought to outperform their “opponent” because they did not form a shared representation that would impact their own responses. de Bruijn et al. proposed that these “fast responders” can attribute their success to one of two factors. The first is not taking their opponent’s actions into consideration and thus not forming a shared representation. Or, in the case that one is

\[\text{RTs for the “fast responders” on corresponding and non-corresponding trials were entered into a one-way repeated measures ANOVA. The analysis showed a significant correspondence effect for “fast responders” } F(1, 10) = 9.02, p < 0.01, \text{ that is to say RTs were significantly faster on corresponding trials than non-corresponding trials. This counters de Bruijn et al.’s (2008) finding that “successful” competitors do not form shared representations.} \]

11 We performed a secondary analysis of our data which took into consideration any differences between “fast” and “slow responders”. RTs for the “fast responders” on corresponding and non-corresponding trials were entered into a one-way repeated measures ANOVA. The analysis showed a significant correspondence effect for “fast responders” \(F(1, 10) = 9.02, p < 0.01\), that is to say RTs were significantly faster on corresponding trials than non-corresponding trials. This counters de Bruijn et al.’s (2008) finding that “successful” competitors do not form shared representations.
formed, this class of participants is better able to inhibit responses. de Bruijn et al. proposed that the degree of task success is rooted in whether shared action representations are formed.

Our present findings suggest that our participants were incorporating the actions of their opponent into their own action plan despite the fact that their opponent’s actions had no bearing on their part of the task. To ensure that a competitive context was maintained throughout the task, RT feedback was presented after every trial for both participants to see. Based on the work of de Bruijn et al. (2008), such participants should not have exhibited a consistent correspondence effect during a competitive joint-action task. Nevertheless, our results demonstrated quite the contrary, showing that participants exhibited a consistent correspondence effect. These results are, however, in line with those of Ruys and Aarts (2010) and Hommel et al. (2009). In agreement with Sebanz et al.’s (2006a, 2006a) thinking, our findings demonstrated that participants formed a representation of not only their own action but also their opponent’s action which affected their performance even in a competitive context. This supports the notion that shared representations are formed even in a competitive context in which two individuals are not striving to achieve a common goal, as is the case when performing a complementary task. Our findings provide further evidence for Sebanz et al.’s (2006a) notion that individuals cannot help but “tune-in” to others.

3.5 Concluding Remarks about Study 1 and 2

The issue we wanted to address originated from Lam and Chua’s (2010) study in which we questioned whether responding to the same S-R alternative may have produced an implicitly competitive context. Despite the fact that participants were never told that they were competing against the other, nor was this ever insinuated, it is possible that instructing
participants to respond to the same S-R alternative unintentionally induced a competitive quality to the task. Bear in mind, the objective of competition is to outperform one’s opponent, even if the task carried out is complementary in nature as was the case in the present study. Success is achieved by focusing on what one needs to do to beat their opponent; however, the social quality of joint action seems to be enough to inadvertently form a representation of even an opponent’s actions. A significant correspondence effect in the Joint Competitive condition supports this latter statement. It also demonstrates that even in a competitive setting, participants formed a shared representation of their action in addition to that of their opponent. Therefore, whether a task is competitive or complementary, shared representations are formed regardless. These results nicely compliment Sebanz et al.’s (2006a) postulation that incorporating another’s action plans with one’s own is both “unintentional and quasi-automatic”, even when another’s actions have no bearing on the task itself.
3.6 Bridging Summary

Study 2 was designed to investigate whether shared representations were still formed in a complementary task performed under the constraints of a competitive situation. Despite the fact that participants were explicitly instructed to outperform their opponent, task co-representation still transpired. Our findings showed that participants formed a representation of not only their own task but also their opponent’s task which affected their performance. They also provide supportive evidence for the notion that individuals cannot help but “tune-in” to others and, in turn, co-represent that other person’s task (Sebanz et al., 2006a).

Having determined that responses to the same stimulus alternative do not elicit a social Simon effect (SSE) (Study 1) and that a representation of another person’s task is still formed even under an explicitly competitive context (Study 2), we identified two necessary conditions under which shared representations are formed. In Studies 3-6, we started to examine spatial coding and response discrimination as factors that may be modulating the joint Simon effect (JSE). While there is a general consensus for the co-representation account, some researchers contend that what gives rise to the JSE is the spatial coding of one’s response with respect to the co-actor’s response (Dolk et al., 2011; Guagnano et al., 2010). To determine if a responses are being coded with respect to location of another relevant stimulus (e.g., the co-actor’s response) we manipulated the relative spatial relationship between participants by having them change seating position from one joint action condition to another. The purpose of Study 3 was to test the spatial-coding account of the JSE. We predicted that spatial recoding would come about when relative seating position changed from one joint action condition to the next.
4  Chapter: Study 3 - Is the Spatial Position of a Co-Actor Coded in Shared Representations?

4.1  Introduction

Our day-to-day activities are not carried out in isolation; as social beings, our lives are rich with human interaction. When we do interact with another person, the task may be as simple as holding the door open for someone or as complicated as moving a piece of furniture with a friend. A greater appreciation for our social nature has led to a shift in the approach taken by cognitive psychologists and cognitive neuroscientists who investigate perception and action. Research in these areas has tended to focus on action at the individual level but more recently consideration has been made for action at the joint level. Clark (1996) puts forth that “a person’s processes may be very different in individual and joint actions even when they appear identical” (p. 19). Consider the act of paddling. If you were to watch someone paddling alone in a canoe in contrast to when they are paddling with another person, chances are you would not be able to identify any overt differences in their actions (other than each person is paddling on opposite sides of the canoe). When we paddle alone, however, the only actions we need to take into account are our own. But if we are the rear paddler, there is the imposed challenge of predicting our co-paddler’s next action to ensure that we coordinate an appropriate action in response to it. This example demonstrates that the processes involved in performing a task under solo conditions are different to those under joint conditions despite the apparent similarity in the initial observation of the act (Clark, 1996).

While joint action can involve two (or more) participants engaging in seemingly identical actions, there are a number of circumstances in which the tendency to imitate
another person’s action needs to be inhibited in order to effectively participate in joint action. For instance, you might ask your friend to pass you your cup of coffee. When receiving the cup, you do not imitate your friend’s action. Instead you select a grip that complements that of your friend to receive the cup successfully. A detail worth highlighting is that throughout the process of having our cup passed to us, we are continually able to observe our friend’s actions. Efforts to better understand how the observation of another person’s actions influences our own have employed paradigms from cognitive psychology and modified them in such a way that the task is shared between two individuals, turning the once solo task into a joint action task. Sebanz et al. (2003a) did exactly this using the Simon paradigm to determine whether paired participants performing this complementary task form shared representations of the other’s task.

Studies of stimulus-response (S-R) correspondence have shown that certain pairings of stimuli and responses result in faster and more accurate performance than others. The most recognized of these studies is the phenomenon of spatial S-R correspondence where responses to a stimulus are faster and more accurate when the stimulus and response set are spatially corresponding (e.g., left response to a left stimulus) than when they are not spatially corresponding (e.g., left response to a right stimulus) (Fitts & Deininger, 1954; Fitts & Seeger, 1953). A variant of spatial S-R correspondence is the Simon effect (SE) in which the irrelevant spatial dimension produces an S-R correspondence effect. In a typical Simon task, the location of the stimuli and responses vary on a common spatial dimension (e.g., left-right) and responses are given on the basis of a non-spatial stimulus feature (e.g., colour). For example, the participant is instructed to make a left key press when a red light is presented and a right key press when a green light is presented (Hedge & Marsh, 1975). Despite the
fact that stimulus location is irrelevant to the task, responses are faster when there is spatial correspondence between the stimulus display and the response set than if there is no spatial correspondence between the two. It has been proposed that a spatial code is automatically generated upon stimulus presentation (Umiltà & Nicoletti, 1985; Wallace, 1971) and that this spatial code overlaps with relevant response code stemming from the non-spatial dimension (Kornblum et al., 1990), which impinges on the selection of a response. Should the irrelevant spatial code and the relevant response code match, response selection is facilitated; if they do not match, response selection is hindered.

To investigate whether individuals represent and integrate another person’s actions into their own action planning, Sebanz and colleagues (2003a, 2005a, 2006b) modified the Simon task to transform it into a social one. Since the Simon task affords two response alternatives, these can be distributed amongst two people, thus creating a complementary joint action task. Sebanz et al. (2003a, 2003b, 2005a, 2006b) transformed the classical Simon task by devising a ‘joint-action’ condition in which the two responses were distributed between two participants. Participants were instructed to base their response on the colour of a ring (red or green) positioned on the index finger of a hand that pointed either to the left or the right. While no correspondence effect was observed when performing the task alone (Individual Go/No-Go condition) (Callan et al., 1974; cf. Ansorge & Wühr, 2004, 2009), when completing the same task alongside another person (Joint Action condition), a correspondence effect arose just as it would if the task was carried out by one person responsible for both S-R alternatives. Sebanz and colleagues (2003a) claimed that these results supported their assumption that participants represented the other person’s S-R alternative, making the seemingly two part task into a whole one; this opportunity, however,
was not afforded in the ‘alone’ condition. They also acknowledged that the spatial codes of
the response sets are part of this shared representation and that the SSE arises as a
consequence of the spatial overlap between the stimulus display and the response set.

Recently, two independent studies have suggested that the SSE may arise as a
consequence of forming a spatial code not only for one’s own response but also for the
response of a co-actor (see Guagnano et al., 2010; Welsh, 2009). Guagnano et al. (2010)
addressed whether shared representations are activated when two people are performing
*independent* tasks rather than a *complementary* one in varying sections of body space (e.g.,
peripersonal, extrapersonal). They postulated that if the joint-correspondence effect was
observed under these circumstances then a shared representation was not necessary to elicit
such an effect. To make the tasks assigned to each participant seemingly independent of each
other, the stimuli were presented at the same time; this was thought to eliminate the turn-
taking aspect of the original joint action task carried out by Sebanz et al., (2003a). On some
trials (20%), only one stimulus appeared on the left or right side of the screen; since a
constant foreperiod was used (500 ms) this trial type was thought to prevent purely automatic
responses. The section of space in which the participants was also manipulated such that the
confederate worked side-by-side in: (1) peripersonal space (within arm-reach) or, (2)
extrapersonal space (beyond arm-reach). Participants were instructed to respond to the
stimulus assigned to them as quickly and accurately as possible. They found, what they
described as, the ‘social Simon effect’\(^\text{12}\) (SSE) when participants performed the non-
collaborative task in each other’s peripersonal space but not in extrapersonal space. They
concluded that eliciting the SSE does not imply that a shared representation has been formed

\(^12\) The term ‘social Simon effect’ will be used to refer to the ‘joint-action effect’ described by Sebanz et al.
(2003a).
but do not discount that this transpires in a complementary task. In addition, they suggest that
the active presence of another person in one’s peripersonal space may offer a spatial
reference for which one can code their actions.

In contrast to Guagnano et al. (2010), Welsh (2009) used the same complementary
task as Sebanz et al. (2003a) in efforts to clarify whether the SE arises due to co-
representation or the spatial coding of a co-actor’s response location. To test their question,
they had paired participants complete the modified Simon task with their limbs (outside arms
or inside arms) either uncrossed or crossed with the other participant’s which allowed for the
dissociation between response co-representation and the spatial coding of a co-actor’s spatial
location. It is the crossed limb condition that will clarify whether the SSE can be attributed to
correlation of spatial coding. Previous studies have examined whether the spatial
correspondence effect arises as a consequence of cerebral laterality or the spatial
correspondence (e.g., Brebner et al., 1972; Proctor & Dutta, 1993; Wallace, 1971).
Comparisons of the spatial correspondence task with uncrossed and crossed limbs in alternate
blocks have shown that the correspondence of the responding effector and stimulus location
is not significant; rather, it is the correspondence between the stimulus and responding hand
location that matters. Based on these findings, Welsh hypothesized that if the SSE is the
result of coding the co-actor’s spatial location then trials on which the stimulus location
corresponded with the location of the responder would have faster RTs than if they were
spatially non-corresponding. In support of co-representation, RTs would be faster when the
stimulus location corresponded spatially with the location of the effector. Welsh (2009)
found that RTs in the joint condition were shorter when the responding effector and stimulus
location were spatially corresponding, which supports the response co-representation account for the SSE.

The contradictory results of Guagnano et al. (2010) and Welsh (2009) illustrate the necessity to further investigate whether the SSE is the result of the co-actor serving as a spatial reference by which the alternative response location can be coded. While our intent is not to refute the notion of co-representation, it may be that spatial information is represented in joint action conditions, which has been suggested by Sebanz et al. (2003a). In order to examine this issue, we manipulated the seating arrangement of participants and the co-actor such that the spatial relationship varied from one joint action condition to another. We wanted to determine if a change in spatial position relative to another (i.e., Participant A on the left of Participant B → Participant A to the right of Participant B) from one joint action condition to next, would result in a spatial re-coding of one’s new position. This would manifest itself in a second identical joint action condition in which the correspondence effect would be observed. Should the correspondence effect be absent in the second joint action condition then it may be inferred that the task representation initially formed in the first joint action condition was preserved and was not updated with a change in personal location relative to the co-actor.

4.2 Methods

4.2.1 Participants

Thirty participants (17 females; mean age = 22.3 years, SD = 4.8 years) were recruited from the undergraduate and graduate student population at the University of British Columbia too participate in the experiment. All but four of the 30 participants were right-handed and all
had normal or corrected-to-normal vision and were naïve to the purpose of the study. The study was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent prior to testing.

4.2.2 Apparatus

Participants sat in front of a 19” computer screen (ViewSonic G90F) with two custom-built single response boxes positioned on the left and right side of the screen. Two chairs were placed side-by-side in front of the monitor and participants were randomly assigned to one of two seats (left or right). Seat position also determined which response hand the participants would be using to execute their response (i.e., left seat, left hand; right seat, right hand). Participants placed their index finger on a single response key placed on the same side as the response hand (e.g., left hand response, response box was positioned to the left of the participant’s midline). The second response box was hidden from the participant during the solo tasks and revealed in those tasks that introduced the co-actor (a confederate). Participants were instructed to keep their inactive hand on their lap.

4.2.3 Stimuli

At the beginning of each trial, a white fixation cross (approximately 2 ° or 2 cm diameter) appeared at the centre of the screen against a black background. Participants were told to fixate at the centre of the cross until the stimulus was presented after a randomly varied foreperiod of 1000, 1400 or 1800 ms. Stimuli consisted of either a blue or orange asterisk (approximately 2 ° or 2 cm diameter) and were presented randomly at a distance of approximately 7 ° or 7 cm to the left or right of fixation. Stimuli remained on the screen for
1250 ms, irrespective of whether a response was selected. After 1250 ms or following a response, the target disappeared and after an inter-trial interval of 2000 ms, the fixation cross reappeared indicating that the next trial was about to begin. This sequence of events was the same each of the experimental tasks. The timing of stimulus presentation and the recording of the time and identity of the response was controlled by an Intel Pentium 3.00 GHz computer running custom E-Prime v2.0 software.

### 4.2.4 Procedures

Participants completed both the individual and joint tasks in one testing session which lasted approximately one hour. The testing session consisted of four main tasks that were performed in the following order: Individual Go/No-Go (IGNG), Joint Action (JA), Joint Action2 (JA2) and 2-choice (TC) tasks (see Figure 4.1 for experimental setup). The IGNG, JA and TC tasks were conceptual replications of the tasks used by Sebanz and colleagues (2003a). The JA2 task, in which we manipulated the relative position of one partner with respect to the other, was unique to the present experiment. Each of the four tasks consisted of two blocks of trials and within a block of trials, the blue and orange asterisks were randomly presented 20 times to the left and right of fixation for a total of 40 stimulus presentations. A total of 320 trials were completed in the entire experiment. Participants were given the opportunity to take a break after each block of trials and to continue on to the next block of trials at their own discretion. The order of the tasks in each testing session was the same for each pair of participants: IGNG, JA, JA2 and TC. Instructions for each task were given both verbally by the experimenter and visually on the computer monitor at the beginning of each task.
Figure 4.1  Seating arrangement of participant (A) and confederate (B) in the IGNG, TC, JA and JA2 tasks.

In the IGNG task, participants were instructed to identify one of two target colours by making either a left or right key press response and to ignore the other one; their inactive hand was placed on their lap. Participants were told that the target could appear to the right or left of fixation but that its location was irrelevant to the task. Participants maintained the same S-R mapping for the one effector in both the JA and TC tasks.

In the two JA tasks, participants continued to respond to the same colour target assigned in the IGNG task, the only difference was that the task was completed with the co-
actor who sat in the once empty seat on either the left or right side of the participant; the seating arrangement was such that it was opposite to the participant’s response hand. The co-actor was instructed to respond to the target colour that the participant was ignoring with the opposite response key (i.e., participant right key press, co-actor left key press).

As previously indicated, the JA task was a conceptual replication of the task carried out by Sebanz et al. (2003a). Our JA2 task differed from the JA task in the following way: while participants maintained their assigned responses to their specified target colour and continued to use the same hand to respond, their seating arrangement was manipulated in one of three ways. In the co-actor-moves condition, the participant remained seated while the co-actor moved to the seat on the opposite side of the participant. For example, if the co-actor was to the left of the participant who sat in the right-side seat, the co-actor’s seat would be moved to the right of the participant. In the participant-moves condition, the co-actor remained seated while the participant moved to the seat on the opposite side of the co-actor. For example, if the participant was to the left of the co-actor who sat the right-side seat, the participant’s seat would be moved to the right of the co-actor. Note that in each of these two seating arrangement conditions, the new seating position was never moved further away in the same direction with respect to their relative spatial position of the person who remained in the same seating position (i.e., to the left of the participant, seating position moves more to the left). In the both-move (BM) condition, the seats were not repositioned rather both the participant and the co-actor got up and changed seats. In turn, the person who sat in the left seat would now sit in the right seat and the person who sat in the right seat would now sit in the left seat. In terms of the instructions given to participants, they were told to continue responding to the same stimulus colour as they had been assigned in the previous task (JA).
At no time were the new response position identified in the instructions (i.e., responses were not distinguished by their new spatial location). In the TC task, one of the two seats was removed and the remaining chair was centred in front of the display monitor.

In the final task (TC), participants were required to complete the entire task on their own where they responded to both the orange and blue stimuli using the left and right response devices. The same S-R mapping for the one effector was maintained in the TC task, while their once inactive effector was used to execute a response to the formerly ignored stimuli. Participants were reminded throughout the experiment that the measure of interest was RT and to respond as quickly and as accurately as possible.

4.3 Results

Response time (RT) data for trials on which participants made an incorrect response or no key press was detected, were eliminated from that data set. The mean error rates for each task were: IGNG condition, 0.0%; TC condition, 1.8%; JA condition, 0.1%; JA2 condition, 0.2%. Error rates for any particular participant did not exceed 5% in any given condition. After removing these trials, the data for each condition were sorted according to trial type (i.e., stimulus colour and location) and any RTs that were less than 100 ms (anticipation error) or greater than 1000 ms (inattention error) were also removed. Once these data were eliminated, mean values of RT were calculated for each trial type and seating condition. When analyzing the TC data, only the RTs for the effector used in the IGNG task were taken into consideration. Data sets from six participants were removed from the analysis for the following reasons: technical malfunction (resulting in the collection of an insufficient
number of trials) and fatigue. Consequently, the data analysis was based on 26 of the 32 participants tested.

Figure 4.2 shows the mean RTs for the four Task conditions. In order to determine whether the spatial correspondence effect was present in a task, we submitted the data for each task condition to separate paired $t$-tests comparing the RTs for corresponding and non-corresponding trials. Corresponding trials are defined as trials in which the stimulus location and the side of response are spatially matched (e.g., right stimulus-right response). Non-corresponding trials are defined as trials on which the spatial dimension of the target and response did not overlap (e.g., left stimulus-right response). The paired $t$-test revealed no significant difference between corresponding ($M = 386$ ms, $SD = 53.5$) and non-corresponding ($M = 387$ ms, $SD = 48.2$) trials in the IGNG task [$t(25) = -0.29, p = 0.77, Cohen's d^{13} = 0.04$] while this difference approached significance [$t(25) = 2.41, p = 0.07, Cohen's d = 0.21$] in the JA task (corresponding: $M = 372$ ms, $SD = 51.6$; non-corresponding: $M = 382$ ms, $SD = 42.1$). These results suggest that performing the Go/No-Go task alone is not significantly different from performing the Go/No-Go task with another person which is not in line with Sebanz et al.’s (2003a) claim that people have a tendency to form shared representations when acting with another in a complementary task. It is worthy to note that while the RT difference between corresponding and non-corresponding trials in our JA task was 10 ms and not statistically significant, other studies have found differences of 11 ms (Sebanz et al., 2003a) and 7 ms (Welsh, 2009) to be statistically significant. As anticipated, the paired-samples $t$-test comparing corresponding and non-corresponding trials revealed a significant difference in the TC task [$t(25) = -4.38, p < 0.01, Cohen’s d = 0.72$] as

---

13 Cohen’s $d$ is used as a measure of effect size.
corresponding trials (M = 464 ms, SD = 58.3) were faster than non-corresponding trials (M = 501 ms, SD = 42.4), showing the SE (decreased RT when irrelevant stimulus location corresponds spatially with response location).

![Figure 4.2](image)

**Figure 4.2** Mean RT on corresponding and non-corresponding trials for the IGNG, TC, JA and JA2 task conditions. The SEM on corresponding and non-corresponding trials, respectively, were 10 ms and 9 ms for the IGNG task; 11 ms and 8 ms for the TC task; 10 ms and 8 ms for the JA task; and 13 ms and 11 ms for the JA2 condition.

Of particular interest to this experiment are those results that arise from the JA2 task condition, as they may resolve the matter of whether the presence of the co-actor induces the spatial coding of the two possible response alternatives. Trials were coded as corresponding or non-corresponding based on the new seating arrangement assigned in the JA2 task condition. For example, if the participant was making a left side response on the left side
with the co-actor’s response occurring on the right side (JA) and their seating position was interchanged (left side to right side) for the JA2 task condition then a “corresponding” trial would now be a right side response to a right stimulus and a “non-corresponding” trial would be a right side response to a left stimulus for the participant. The paired t-test revealed no significant SSE in the JA2 task condition, \( t(25) = 0.75, p = 0.46 \), Cohen’s \( d = 0.06 \); corresponding trials (M = 395 ms, SD = 64.5), non-corresponding trials (M = 391 ms, SD = 57.0).

### 4.4 Discussion

To investigate how another person’s actions can influence one’s own actions, Sebanz and colleagues (2003a) used a modified variant of the Simon task in which participants performed the task alone or alongside another active participant (the co-actor). Over the years the research on representation and coding with respect to the correspondence effect has recognized that stimuli can be coded according to multiple reference points (see Lamberts et al., 1992). It is not, therefore, surprising that researchers have begun to question whether the co-actor served as a reference point for coding response positions as left or right (see Guagnano et al., 2010; Philipp & Prinz, 2010; Welsh, 2009). Recall that in Sebanz et al.’s (2003a) JA condition, participants sat beside the co-actor who was either to the left or the right of them. Depending on the co-actor’s seating assignment, it is possible that participants may have spatially coded their personal space relative to the co-actor which would in turn influence response time. In forming these left and right spatial codes of the available responses, the SSE could have been elicited by the dimensional overlap between the stimulus and response sets (see Kornblum et al., 1990). In contrast, the absence of the co-actor in the
Individual Go/No-Go condition prevented the potential referencing of the alternative response location and as such the participant should not spatially code their response. This reasoning would account for why response times are not influenced by the irrelevant spatial feature of the stimulus (i.e., direction finger is pointing). Therefore, the argument exists that the presence of the co-actor may have provided a spatial reference point for which participants were not only able to discriminate and spatially code their own response but also that of the co-actor.

The goal of our experiment was to test the alternative explanation that the presence of the co-actor served as a spatial reference point which led to the spatial coding of the co-actor’s response. To address this matter participants and the co-actor would switch their seating position relative to each other after having completed one of two JA conditions to determine whether participants would re-code response location with reference to their new seating arrangement. Our results did not offer convincing support for this alternative account of the SSE. We did replicate the typical SE (Simon, 1990) in the TC condition and did not observe the correspondence effect in the IGNG condition (cf. Ansorge & Wühr 2004, 2009; Hommel, 1996) which has been shown in previous joint action studies (see Sebanz et al., 2003a, 2005b). Although the analysis of mean RTs did not show any reliable evidence for the SSE in the JA condition in which participants performed in a complementary task alongside the co-actor, the non-significant difference of approximately 10 ms does show a trend toward faster RTs in corresponding than non-corresponding trials.\(^1\)

\(^1\) An important point to make is that the RT differences between spatially corresponding and non-corresponding trials in the JA condition (10 ms) that we report are in the same range as other joint action studies. In their original study, Sebanz et al. (2003a) identified a SSE of 11 ms ($p < .001$), in a subsequent ERP study their RT data showed a SSE of approximately 9 ms ($p < .05$). The variability our RT data in the corresponding (SD = 52 ms) and non-corresponding trials (SD = 42 ms) in the JA condition may contribute to
We had expected that if the SSE depended on implicitly coding one’s position relative to the co-actor, changing the direction of this spatial relation would lead to participants re-coding their new position and maintaining the correspondence effect. Our results showed that despite the change in the participant’s position relative to the co-actor, the correspondence effect did not manifest itself (corresponding = 395 ms, non-corresponding = 391 ms). The absence of the correspondence effect under these circumstances suggest that switching the spatial position of the participant relative to the co-actor did not induce a ‘recoding process’ of the S-R mapping previously assigned in the JA condition. This spatial recoding would entail an updating of the assigned S-R mapping from the JA condition to account for the participant’s new personal location. If this recoding process had taken place then a participant who initially coded their response as left and that of the co-actor as right, for example, then in the JA2 condition they would recode their response according to their new seating arrangement thus forming a new shared representation. What we would have observed were faster RTs in the corresponding trials than in the non-corresponding trials in the JA2 condition. While our results may not be in line with the notion that spatial coding is responsible for SSEs, it is worth noting that the difference in the JA condition went from 10 ms to -4 ms in the JA2 condition which suggests that the new seating alignment was potentially having some sort of impact on a participant’s behaviour.

Our results seem to suggest that the SSE does not arise as a result of spatial coding. We found that participants did not re-map their personal location when their position relative to the co-actor changed which would have been demonstrated had the correspondence effect

---

our non-significant finding. Sebanz et al. (2003a) reported standard deviations of 32 ms in both the corresponding and non-corresponding trials in their JA condition.
in the subsequent JA2 condition been observed. In spite of this, it is possible that our manipulation of relative spatial position had a greater disruptive influence on performance in the JA2 task than anticipated. As a consequence, spatial coding was impacted such that any recoding of response position was abandoned hence the absence of a SE or even the finding of a negative SE. Perhaps a more subtle manipulation is necessary to determine whether the joint SE is truly evidence for shared task representations or simply a form of spatial response coding.
4.5 Bridging Summary

In our third study we tested the spatial-coding account, more specifically that the presence of a co-actor may serve as a spatial reference point which brings about the joint Simon effect (JSE). We anticipated that changing the relative spatial relationship between participants from one joint action condition to another would lead to the recoding of response location. Our results were not consistent with the spatial-coding account as a JSE did not manifest itself subsequent to a change in seating position. However, we could not dismiss the possibility that the reason why we did not find evidence in favour of this alternative spatial-coding explanation was because changing the seating arrangement proved to be too disruptive to the task. As a result, spatial coding may have been impacted in such a way that the recoding of response location was canceled leading to neither a SE nor a negative SE.

The purpose of Study 4 was to re-assess the spatial-coding account by introducing a more subtle manipulation to test this alternative explanation for the JSE. In this chapter, we introduce the response-discrimination hypothesis (RDH) which offers a number of explanations for the exceptions to the standard finding of the SE, one of which is the observation of a SE in the Go/No-Go task (see Ansorge & Wühr, 2004). According to the RDH, a SE can be elicited in a Go/No-Go task if it is preceded by a 2-choice (TC) task. In a TC task, it is useful to discriminate the alternative responses according to their spatial position; these responses are then represented and stored in working memory. This response representation can then carry over to a subsequent task which may not otherwise necessitate the discrimination of alternative responses such as the single response Go/No-Go task. We examined whether the SE could be elicited in a Go/No-Go task when it was preceded by a Go/No-Go task using the reverse S-R mapping, a joint action (JA) task, or a TC task. We also
included a task sequence in which a JA task was preceded by a TC task to test whether exposure to a more salient discrimination between responses could enhance the observed SE in a JA task. We anticipated a SE when the Go/No-Go task was preceded by the TC task and the JA task because it would be beneficial to discriminate the response alternatives according to their spatial location within the task. Even though S-R mappings were interchanged from one Go/No-Go task to the next, we did not expect a carryover effect since discrimination between alternative responses was not necessary within a single task.
5 Chapter: Study 4 - Can Prior Exposure with Alternative Response Discrimination Influence Responses in an Individual Go/No-Go Task?

5.1 Introduction

Joint action has emerged as a topic of scientific interest in the discipline of social cognitive neuroscience. Recent studies have set out to try and identify the mechanisms that allow two or more individuals to successfully coordinate their actions in order to achieve common goals. To select an effective and appropriate response that will complement another’s action, rather than simply imitating it, there needs to be a way to predict what someone will do next. Such a predictive means would facilitate action planning and avert a reactive response on the part of the observer. For example, when one has knowledge of the stimulus conditions under which someone will make a particular response, there is a strong tendency for one to form shared task representations which are activated (or suppressed) when that stimulus is presented (Sebanz et al., 2006a). This predictive mechanism is valuable to joint action because it allows one to prepare actions in advance even in the case that that action cannot be observed. Support for this notion of co-representation comes from a series of experiments that customized the classical Simon task into an “interactive” one.

Sebanz et al. (2003a, 2005a) offered some of the first evidence that individuals form shared representations when engaged in a turn-taking (or complementary) task. Using a variant of the Simon task, participants performed one part of the two-part task alone (Individual Go/No-Go task) or together with another person (Joint Go/No-Go task). In the Individual Go/No-Go (IGNG) task, participants are instructed to respond to one of two non-spatial stimulus features (green ring) by making a key press while ignoring the other stimulus
feature (red ring). In the Joint Go/No-Go (JA) task, participants perform the same task but alongside another person who responds to the once ignored stimulus feature (red ring). The Simon effect (SE) is a robust and replicable phenomenon with magnitudes ranging from 20-40 ms in a 2-choice reaction task, this effect is by and large absent in a Go/No-Go task (cf., Ansorge and Wühr, 2004, 2009). Joint action studies have noted the absence of the SE in the individual setting but have observed its re-emergence in the joint setting; this has been described as the ‘joint-correspondence effect’ or the ‘social Simon effect’ (SSE). What is most compelling about these findings is that participants are performing the exact same task under each setting, yet their performances changes such that it is as if they are carrying out the whole task (i.e., 2-choice task) on their own. These findings form the crux of the claim that there truly is task co-representation in the joint setting. This has been corroborated by neurophysiological studies that have shown that the No-Go P3 component (associated with response inhibition and action control) was significantly larger in the joint condition than in the individual condition. This amplitude difference suggests that there was stronger response inhibition on no-go trials in the joint condition because the co-actor’s response alternative was represented, activated and in turn needed to be inhibited (Sebanz et al. 2006b; Tsai et al., 2006, 2008).

An alternative account for the SSE has been proposed based on the findings of a study conducted by Ansorge and Wühr (2004). Most of the explanations for the SE distinguish between two parallel routes of response selection: a conditional pathway that processes task-relevant information to select the correct response based on the instructed stimulus-response mapping and an automatic pathway along which stimulus location activates a spatially corresponding response irrespective of the task instructions (Hommel,
1997; Kornblum et al., 1990; Zhang et al., 1999). Ansorge and Wühr do not refute this
account for the SE; however, they make the case that there are a number of exceptions to the
standard finding of a SE that dual route models (e.g., dimensional overlap model, see
Kornblum et al., 1990) fail to explain. To fill in these gaps, they outline a response-
discrimination hypothesis (RDH) which proposes that when a task affords the discrimination
of response alternatives according to spatial features (e.g., left-right) which are then
represented in working memory (WM), the SE can be elicited.

One of the conditions where the SE does not typically occur is in a simple reaction
time (SRT) task or in a discrimination task (or Go/No-Go task). A SRT task involves
responding to one stimulus, such as pressing a button as quick as possible every time the ‘go’
signal appears. A Go/No-Go task requires participants to discriminate between ‘go’ and ‘no-
go’ signals and to press a button when one stimulus type appears and to withhold a response
when another stimulus type appears. Callan et al. (1974) reported a considerable reduction in
the SE when participants performed a Go/No-Go task compared to a choice RT task and they
attributed this to the minimization of the response selection process. The RDH imparts an
alternative explanation in which task context is taken into account. The Go/No-Go task
involves a single response which does not necessitate it to be discriminated with respect to an
alternative response by means of particular spatial codes (e.g., left-right). In contrast, the
choice RT task affords two response alternatives which provides an alternative spatial code
(left vs. right) to represent the responses in WM and also proves useful to the task itself. In
the case of Callan et al.’s residual SE in the Go/No-Go task, Ansorge and Wühr (2004) point
out that half the participants performed the choice RT task prior to the Go/No-Go task and
that the WM representations of the responses may have carried over the ordering of these two
tasks. Again, in the choice RT task, responses were spatially represented in WM and persisted in the Go/No-Go task inducing the diminished SE. Support for this came from Ansorge and Wühr’s (2004) Experiment 4 in which they observed a significant SE when the Go/No-Go task was preceded by a choice RT task which required participants to choose between a left and a right response according to a non-spatial stimulus feature.

The present study was motivated by the predictions made by the RDH to explain Callan et al.’s (1974) findings. Our aim was to establish whether performing a task in which alternative responses could be represented according to spatial location prior to an IGNG task could elicit a residual SE. Once more, the RDH predicted a SE in a choice RT task because left-right response decisions were required. What has yet to be explored is whether the two response alternatives afforded in a JA task are discriminated and represented by means of spatial codes even though participants are pressing a single response key. The bias to discriminate between alternative responses may be prompted since response assignments are designated to participants at the start of the task even though participants are only responsible for making a single key press response. If this is the case then the spatial response representations in WM should carry over from the JA task to an IGNG task. In contrast, the absence of a SE in an IGNG task following the JA task could suggest one of two possibilities. First, the underlying mechanisms of the SSE attributed to co-representation differ from those in a traditional Simon task. It may be that shared representations are only sustainable in a social context and do not persist once the task context changes. Second, the effective discrimination of alternative responses may require participants to make use of both alternative responses (e.g., TC task) and the nature of the JA task may be too superficial for it to be a context conducive for spatial response codes to represent the responses.
We designed four unique task sequence groups to test whether SEs could be observed in a Go/No-Go task (see Table 5.1 for conditions and predictions of the experiment). The task sequence for one group of participants was: IGNG-BASELINE, IGNG-PRETEST, IGNG-OPPOSITE KEY, IGNG-POSTTEST. The IGNG-OPPOSITE KEY task required participants to change response hands (e.g., left → right) as well as the stimulus colour they were responding to (e.g., orange → blue). Perhaps the switching from one response hand to the other from one task to the next is enough to foster a degree of spatial discrimination of even a single response (see Hommel, 1996, Experiment 3) in which a SE is found in the pretest. Another group of participants performed the following task sequence: IGNG-BASELINE, IGNG-PRETEST, TC-EXPOSURE, IGNG-POSTTEST. This task sequence was essentially our attempt to replicate the findings of Ansorge and Wühr (2004, Experiment 4) and to confirm the predictions made by the RDH. Participants assigned to the third group completed this sequence of tasks: IGNG-BASELINE, IGNG-PRETEST, JA, IGNG-POSTTEST. Response representations may be formed as a consequence of task sharing (co-representation) or response discrimination (RDH) and the presence of a SE in the posttest would speak to this. The final task sequence was: IGNG-BASELINE, JA-PRETEST, TC-EXPOSURE, JA-POSTTEST. The SSE tends to be much smaller than a regular SE. By interleaving a TC task between the pretest and posttest, the influence that a task in which a decision needs to be made between two possible responses may have on the magnitude of the posttest SSE can be evaluated.
We offer two sets of predictions as per the RDH and the co-representation account, respectively. In line with the RDH, SEs are not expected in the IGNG-BASELINE or IGNG-PRETEST tasks for any of the four task sequence groups since the behavioural context does not require the single response to be spatially discriminated. We do not anticipate a SE in the IGNG-OPPOSITE KEY task. As far as we are aware of, the evaluation of task requirements that involve a single response has not been carried out and accounted for by the RDH. From the predictions made about the conditions under which a SE would be observed by the RDH, we would expect that because the two response keys did not need to be discriminated within the performance of the task then it would not be necessary to form a spatial representation of the alternative responses and in turn store in WM. For similar reasons, we did not expect to find a SE in a subsequent Go/No-Go task (IGNG-POSTTEST task). The RDH predicts a SE in both TC-EXPOSURE tasks because performance will benefit from the discrimination of the two response alternatives in terms of spatial codes. The spatial response representation stored in WM from the TC-EXPOSURE task is expected to carry over to the IGNG-POSTTEST task as previously shown by Ansorge and Wühr (2004, Experiment 4). In the JA task, participants and co-actors are each assigned alternative responses which could be referenced to specific spatial codes and represented as such. Is it sufficient for the task context to afford the opportunity to spatially discriminate two alternative responses for them.

### Table 5.1 Table of experimental conditions, task sequences and predictions made by the response discrimination hypothesis (RDH) and a co-representation standpoint for each of the four task sequence groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Pretest</th>
<th>Exposure</th>
<th>Posttest</th>
<th>Predictions (RDH)</th>
<th>Predictions (Co-Representation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IGNG</td>
<td>IGNG</td>
<td>IGNG-OPPOSITE KEY</td>
<td>IGNG</td>
<td>No Carryover Effect</td>
<td>No Carryover Effect</td>
</tr>
<tr>
<td>2</td>
<td>IGNG</td>
<td>IGNG</td>
<td>TC</td>
<td>IGNG</td>
<td>Carryover Effect</td>
<td>Carryover Effect</td>
</tr>
<tr>
<td>3</td>
<td>IGNG</td>
<td>IGNG</td>
<td>JA</td>
<td>IGNG</td>
<td>Carryover Effect</td>
<td>No Carryover Effect</td>
</tr>
<tr>
<td>4</td>
<td>IGNG</td>
<td>JA</td>
<td>TC</td>
<td>JA</td>
<td>Carryover Effect</td>
<td>JA Effect</td>
</tr>
</tbody>
</table>
to be represented and stored in WM? The RDH has never presented a prediction for such a task; however, drawing from their predictions of a SE in a choice RT task, we expect the SE in all three JA tasks (JA, JA-PRETEST, JA-POSTTEST). Since spatial features discriminate between the two responses in the JA task, they should be represented in WM, in turn giving rise to the SE. If this is the case, the SE should also be observed in the IGNG-POSTTEST task even though it does not require response discrimination because the response representation should carry over from the JA task. Finally, the prospect of an enhanced SE in the JA-POSTTEST task following the TC-EXPOSURE task is uncertain. While Ansorge and Wühr (2004) found a sizeable SE (29 ms) in their Go/No-Go task following a TC task, the possibility of enhancing a pre-existing SE has not been considered.

Predictions based on a co-representation account are as follows. Since the IGNG-BASELINE, IGNG-PRETEST and IGNG-POSTTEST tasks are performed alone, there is no ‘other’s’ task to represent and a SE should not be observed under these conditions for any of the four task sequence groups. Despite switching response hands in the IGNG-OPPOSITE KEY task, a SE should not arise for the same reason a SE would not be found in the IGNG-BASELINE, IGNG-PRETEST and IGNG-POSTTEST tasks. The two TC-EXPOSURE tasks should result in the typical SE due to interference between the spatial dimension of the stimulus and the response. The co-representation account would predict a SSE in every JA task (JA-EXPOSURE, JA-PRETEST, JA-POSTTEST) because not only does one represent their own response alternative but also that of the co-actor which would evoke response conflict.
5.2 Methods

5.2.1 Participants

A group of 41 undergraduate students (26 females; mean age = 23.0 years, SD = 4.6 years) completed this experiment. All participants, with the exception of three, were right-handed, had normal or corrected-to-normal vision, and were naïve with regard to the hypotheses of this experiment. All participants gave a written informed consent to participate in the study, which was conducted in accordance with the ethical guidelines set out by the University of British Columbia.

5.1.1. Apparatus

Testing took place in a dimly lit room with a computer monitor (ViewSonic G90F 19 in.) set in the middle of a desk. Two chairs were placed side-by-side in front of the monitor. Participants were randomly assigned to one of two seats (left or right); seat position also determined response hand (i.e., left seat: left hand, right seat: right hand). Participants put their index finger on a single response key placed on the same side as the response hand (e.g., left hand response, response key to the left of participant’s midline). Participants kept their inactive hand on their lap.

5.2.2 Stimuli

The sequence of events in each trial was as follows. After an intertrial interval of 2000 ms, a white fixation cross (1° X 1°) was displayed at the centre of the computer monitor against a
black background for a randomly determined interval of 1000, 1400 or 1800 ms. This was followed by the stimulus which could be either a blue or orange asterisk (2° X 2°) randomly presented to the left or right of fixation at a distance of 7°. The stimulus remained on the screen for 1250 ms, irrespective of whether a response was given. Participants received a feedback message indicating if an error (e.g., wrong key press) was made.

5.2.3 Procedures

Participants completed four separate tasks in a single testing session. In the standard Simon (TC) task, participants were asked to respond to the blue or orange asterisks by pressing either a left or right response key with the index finger of their left or right hand (i.e., blue asterisk-left response, orange asterisk-right response). They were told that the stimulus could appear on either side of the display but that this was irrelevant to the task. In the IGNG task, participants were instructed to respond to one stimulus colour (e.g., blue) using only one of two response keys (e.g., left response) while ignoring the other one (e.g., orange). The JA task was identical to the IGNG task except participants performed the task alongside a co-actor (a confederate) who used the opposite response key (e.g., right response) to respond to the once ignored stimulus colour (e.g., orange).

Participants were randomly assigned to one of four task sequence groups. The IGNG task sequence group served as a control group in which participants completed four IGNG task back-to-back (IGNG-BASELINE, IGNG-PRETEST, IGNG-OPPOSITE KEY, and IGNG-POSTTEST). Participants assigned to this group would, for example, be asked to place their left index finger on the left response key and to respond whenever an orange stimulus appeared and to ignore the blue stimulus when it appeared in both the IGNG-
BASELINE and IGNG-PRETEST tasks. After having completed these first two tasks, they would proceed to the IGNG-OPPOSITE KEY task in which they would be instructed to respond to the once ignored stimulus colour (blue) using the opposite index finger and the opposite response key (left index finger, left response key → right index finger, right response key). Finally, in the IGNG-POSTTEST task, participant reverted back to their original stimulus-response assignment (left response-orange stimulus). Those participants assigned to the TC task sequence group performed the IGNG-BASELINE and IGNG-PRETEST tasks first, followed by the TC-EXPOSURE task and finished with the IGNG-POSTTEST task. The JA task sequence group performed the IGNG-BASELINE and IGNG-PRETEST tasks first, followed by the JA-EXPOSURE task and finished with the IGNG-POSTTEST task. Finally, the JA-TC-JA task sequence group performed the IGNG-BASELINE task first, then the JA-PRETEST task, followed by the TC-EXPOSURE task, and finished with the JA-POSTTEST task.

Each task sequence group started off with the IGNG-BASELINE task in an attempt to establish whether the SE or even a reduced effect was present to begin with. After having completed the baseline task, participants were given a mandatory break of approximately five minutes. We used a pretest-posttest design to compare and measure any changes in performance resulting from the experimental task (e.g., IGNG-OPPOSITE KEY, TC-EXPOSURE, JA-EXPOSURE tasks). Hence the IGNG-PRETEST task served as a pretest and the IGNG-POSTTEST task served as a posttest; inferences about the influence that the experimental task may have had on performance were then made based on any observed differences between the pretest and posttest (i.e., carryover effects). Participants performed 12 practice trials at the beginning of each of the four tasks in a task sequence. Each task was
made up of 80 randomly mixed experimental trials, whose type resulted from the factorial combination of stimulus type (orange or blue asterisk) and stimulus location (left or right) thus appearing an equal number of times. The testing session lasted approximately an hour.

5.3 Results

Each groups’ data were first separated according to task then sorted according to stimulus type and stimulus location. Erroneous trials (e.g., wrong key was pressed, no response detected) and any response times (RT) below 100 ms (anticipation) or above 1000 ms (misses) were removed from each data set. In addition, for each participant, RTs more than two standard deviations above or below the mean for each trial type in a task were also removed from the statistical analyses. The error rate for the IGNG, TC and JA task sequence groups was 0.0%. The error rate for the JA-TC-JA task sequence group was 0.1%. Note that the means for the TC task were derived only from the same hand that was used by a participant in the IGNG and JA tasks. The data for each group were submitted to similar separate paired-sample t tests and repeated measures ANOVAs (as detailed below). Note that when trials are described as ‘corresponding’ and ‘non-corresponding’, we are referring to the spatial correspondence between stimulus and response location.

Figure 5.1 shows the mean RTs and standard error of the mean (SEM) for corresponding and non-corresponding trials across the four tasks for the IGNG task sequence group. There was no difference between corresponding and non-corresponding trials in any of the IGNG tasks analyzed for the IGNG task sequence group. A paired-sample t test showed that in the IGNG-BASELINE task, corresponding trials ($M = 425$ ms, $SD = 68.3$) were no faster than non-corresponding trials ($M = 435$ ms, $SD = 81.5$) ($t(10) = -1.01, p =$
When participants performed the IGNG-OPPOSITE KEY task and responded to the once ignored stimulus using the opposite response key, there was still no difference between corresponding (M = 436 ms, SD = 63.4) and non-corresponding (M = 441 ms, SD = 60.1) trials [t(10) = -0.50, p = 0.62, Cohen’s d = 0.07]. Next, we compared the IGNG-PRETEST and the IGNG-POSTTEST tasks to assess if the IGNG-OPPOSITE KEY task had any carry over effect. The findings of a 2 Task (IGNG-PRETEST, IGNG-POSTTEST) X 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA revealed a significant main effect for task [F(1, 10) = 5.67, p = 0.04], showing faster RTs in the pretest (419 ms) compared to the posttest (440 ms); this may be attributable to fatigue. No other main effect or interaction approached significance. The absence of an interaction between task and correspondence shows that performing the IGNG-OPPOSITE KEY task to respond to the once ignored stimulus feature does not modify performance in the IGNG-POSTTEST task.
Figure 5.1  Mean RT on corresponding and non-corresponding trials for the IGNG task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 20 ms and 24 ms for the IGNG-BASELINE task; 19 ms and 21 ms for the IGNG-PRETEST task; 18 ms and 17 ms for the IGNG-OPPOSITE KEY task; and 18 ms and 18 ms for the IGNG-POSTTEST task.

Figure 5.2 shows the mean RTs and SEM for corresponding and non-corresponding trials across the four tasks for the TC task sequence group. In the TC group, we first compared corresponding and non-corresponding trials in the TC-EXPOSURE task to determine if there was a SE. The analysis revealed a significant difference [$t(9) = -3.29, p < 0.01$, Cohen’s $d = 0.69$] between corresponding (M = 461 ms, SD = 65.3) and non-corresponding (M = 508 ms, SD = 69.9) trials revealing the SE as anticipated. A paired-sample $t$ test showed that in the IGNG-BASELINE task, the RTs on corresponding trials (M
were no different than those on non-corresponding trials (M = 440 ms, SD = 70.3) [t(9) = -1.57, p = 0.15, Cohen’s d = 0.12]. The RT data for the IGNG-PRETEST and IGNG-POSTTEST tasks were submitted to a 2 Task (PRETEST, POSTTEST) X 2 Correspondence repeated measures ANOVA. The analysis showed a main effect for correspondence [F(1, 9) = 5.17, p < 0.05] with RTs being faster on corresponding (421 ms) than on non-corresponding (433 ms) trials. There was no main effect for task [F(1, 9) = 2.99, p = 0.12]. There was also no interaction between task and correspondence [F(1, 9) = 0.61, p = 0.45]. The lack of an interaction suggests that there was no difference in the direction or magnitude of the SE in the IGNG-PRETEST and IGNG-POSTTEST tasks. A paired-sample t-test was run on the data to confirm whether the SE was similarly present or absent in both the pretest and posttest. Responses were not significantly different on corresponding (M = 412 ms, SD = 64.4) and non-corresponding (M = 422 ms, SD = 63.5) trials [t(9) = -1.53, p = 0.16, Cohen’s d = 0.15] in the IGNG-PRETEST task (i.e., no Simon effect). The paired-sample t test for the IGNG-POSTTEST task data showed that responses were on average 16 ms faster on corresponding (M = 429 ms, SD = 54.4) than non-corresponding (M = 445 ms, SD = 65.4) trials [t(9) = -3.29, p < 0.01, Cohen’s d = 0.26]. This post-hoc analysis suggests that the spatial response representation formed in the TC-EXPOSURE task may have indeed carried over to the IGNG-POSTTEST task after all.
Figure 5.2  Mean RT on corresponding and non-corresponding trials for the TC task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 22 ms and 22 ms for the IGNG-BASELINE task; 20 ms and 20 ms for the IGNG-PRETEST task; 21 ms and 22 ms for the TC-EXPOSURE task; and 17 ms and 21 ms for the IGNG-POSTTEST task.

Figure 5.3 shows the mean RTs and SEM for corresponding and non-corresponding trials across the four tasks for the JA task sequence group. A paired-sample t test revealed no significant difference in the RTs for corresponding (M = 476 ms, SD = 68.5) compared to non-corresponding (M = 484 ms, SD = 72.0) trials [t(9) = -0.75, p = 0.47, Cohen’s d = 0.11] in the IGNG-BASELINE task. We also conducted an analysis on the RT distributions for the corresponding and non-corresponding trials in the JA task using a paired-sample t test. There was no difference in RTs between corresponding (M = 442, SD = 54.7) and non-
corresponding (M = 444, SD = 54.4) trials [t(9) = -0.16, p = 0.88, Cohen’s d = 0.03] which fails to support the co-representation account. This clearly posed a problem as the aim of this study was to investigate whether performance in tasks, such as the TC-EXPOSURE and the JA-EXPOSURE, in which spatial response features could be used to represent alternative responses, could give rise to the SE in a Go/No-Go task. Despite not having replicated the SSE in the JA-EXPOSURE task, we continued on with the analyses we initially set out to run for all groups. As expected, a repeated measures ANOVA with the factors of Task (IGNG-PRETEST, POSTTEST) and Correspondence showed no main effect for task [$F(1, 9) = 2.41$, $p = 0.16$], nor correspondence [$F(1, 9) = 0.90$, $p = 0.37$]. There was also no interaction between these two factors [$F(1, 9) = 0.04$, $p = 0.85$]. As a result of not having observed the SSE in the JA-EXPOSURE task, we were unable to make any inferences about a possible carryover effect from the JA-EXPOSURE task to the IGNG-POSTTEST task.
Figure 5.3  Mean RT on corresponding and non-corresponding trials for the JA task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 22 ms and 23 ms for the IGNG-BASELINE task; 19 ms and 20 ms for the IGNG-PRETEST task; 17 ms and 17 ms for the JA-EXPOSURE task; and 22 ms and 19 ms for the IGNG-POSTTEST task.

Figure 5.4 shows the mean RTs and SEM for corresponding and non-corresponding trials across the four tasks for the JA-TC-JA task sequence group. We first assessed the mean RTs in the TC-EXPOSURE task. The paired-sample $t$ test revealed a significant difference [$t(9) = -2.27, p < 0.05$, Cohen’s $d = 0.30$] between corresponding ($M = 539$ ms, SD = 73.5) and non-corresponding trials ($M = 565$ ms, SD = 96.2) which is consistent with previous studies (Simon, 1969; 1990). We analyzed the RTs in the IGNG-BASELINE task, entering the data into a paired-sample $t$ test and the differences were non-significant (corresponding:
M = 509 ms, SD = 85.5; non-corresponding: M = 502 ms, SD = 85.0) \[t(9) = 0.64, p = 0.54, \]
Cohen’s \(d = 0.08\]. The mean RTs for the JA-PRETEST and JA-POSTTEST tasks were submitted to a repeated measures ANOVA with Task (JA-PRETEST, POSTTEST) and Correspondence as within-subjects factors. Neither the main effect of task \([F(1, 9) = 3.76, p = 0.08]\), correspondence \([F(1, 9) = 0.35, p = 0.57]\), nor the interaction \([F(1, 9) = 2.01, p = 0.19]\) reached statistical significance. To identify if there was a SSE in either of the JA tasks, we ran separate paired-sample \(t\) tests and found that the SSE was absent in both the JA-PRETEST (corresponding: M = 451 ms, SD = 53.1; non-corresponding: M = 446 ms, SD = 41.8) \[t(9) = 0.48, p = 0.64, \]
Cohen’s \(d = 0.11\] and JA-POSTTEST (corresponding: M = 461 ms, SD = 58.0; non-corresponding: M = 476 ms, SD = 72.4) \[t(9) = -1.40, p = 0.19, \]
Cohen’s \(d = 0.22\] tasks. Despite these non-significant findings, it was interesting to note that the difference between corresponding and non-corresponding trials went from -5 ms in the JA-PRETEST task to 15 ms in the JA-POSTTEST task\(^{15}\).

\(^{15}\) This difference was calculated as follows: \(RT_{\text{non-corresponding trials}} - RT_{\text{corresponding trials}}\)
Figure 5.4  Mean RT on corresponding and non-corresponding trials for the JA-TC-JA task sequence group. The SEM on corresponding and non-corresponding trials, respectively, were 27 ms and 27 ms for the IGNG-BASELINE task; 17 ms and 13 ms for the JA-PRETEST task; 23 ms and 30 ms for the TC-EXPOSURE task; and 18 ms and 23 ms for the JA-POSTTEST task.

5.4  Discussion

The present study was motivated by the work of Ansorge and Wühr (2004) and aimed to test whether a SE could be elicited in an IGNG task when it was preceded by a task in which the spatial features of alternative responses could be integrated into the response representation stored in WM (e.g., JA-EXPOSURE, TC-EXPOSURE tasks). These findings would allude to potential preconditions in which the “SSE” could be observed that are not necessarily attributable to task co-representation. The rationale behind this study was based
on the explanation provided by the RDH for Callan et al.’s (1974) observation of a diminished SE in a Go/No-Go task. Ansorge and Wühr (2004) pointed out that half of the participants in Callan et al.’s experiment performed a choice RT task prior to the Go/No-Go task. According to the RDH, a SE could have been elicited in the go/no-go task because the WM representations of the responses were carried over from the choice RT task to the Go/No-Go task. Granted, the predictions made by the RDH for what conditions a SE will arise were with respect to performance in a solo context but do they also apply to performance in a social context? If the SSE observed in JA tasks is truly ascribed to task co-representation (i.e., representation of one’s own and other’s response alternatives) then the SE should be absent when one subsequently performs the IGNG task because there is only one response and no co-actor’s task to represent, thus no response conflict should occur. In line with the RDH, we hypothesized that a task that affords the discrimination of response alternatives along a spatial dimension (e.g., horizontal dimension) would create necessary preconditions for the SE to emerge in an IGNG task. If our logic is correct then the SE should be elicited in the IGNG task when it is preceded by the JA task because horizontal codes would be useful for response discrimination and thus represented in WM as so. This WM representation of the responses would then carry over from the JA task to the IGNG task.

Our efforts to test our hypotheses were hampered by our failure to find a significant SSE in any of our JA tasks. Comparisons of mean RTs in the JA tasks performed by both the JA and the JA-TC-JA task sequence groups showed no significant difference between corresponding and non-corresponding trials. It is worthy to note that the magnitude of the SSE in the JA-PRETEST task was quite negligible (-5 ms) but a sizable difference (15 ms)
was observed in the JA-POSTTEST task in the JA-TC-JA task sequence group. Had the difference between corresponding and non-corresponding trials in the JA-POSTTEST task reached statistical significance, we would have interpreted these results to reflect a carryover of spatial response representations from the TC-EXPOSURE task to the JA-POSTTEST task giving rise to a “SSE”. In this case, the absence of the SSE in the JA-PRETEST task would have made a strong case for this line of reasoning. A more detailed discussion of the results for each of the four task sequence groups will now follow.

The lack of a SE in any of the four IGNG tasks performed by those participants in the IGNG task sequence group is in accordance with the predictions laid out by the RDH (Ansorge & Wühr, 2004; Wühr & Ansorge, 2007). According to the RDH, if spatial codes are selected to represent response location in WM and are useful in discriminating between functionally alternative responses then the SE should be observed. In the Go/No-Go task there is only one response and therefore its location is not useful in discriminating it from another response alternative as would be the case in a TC-EXPOSURE task. The representation of that single response in WM may be to activate or inhibit that response but it would make little sense to represent that response along a spatial dimension. Our results fit with this explanation as to why a SE was not observed in any of the four IGNG tasks performed by the IGNG task sequence group. We also extend the work of Ansorge and Wühr (2004), demonstrating that responding to the once ignored stimulus using the opposite response key does not create a context that makes it useful for participants to discriminate between alternative responses along the spatial dimension in turn giving rise to the SE. To our knowledge, no one has tested whether alternating the use of one of two responses from one Go/No-Go task to the next would be sufficient to subsequently represent the spatial
location of both responses and transfer between Go/No-Go tasks. According to the RDH, a SE should not be elicited throughout a sequence of separate Go/No-Go tasks, regardless of whether alternative responses were used because the two responses were not discriminated within the performance of a task. Our results suggest that for a SE to be observed in a Go/No-Go task, the task that precedes it requires that the alternative responses be discriminated according to spatial location within the task; spatial response representations do not accrue across tasks. It is not enough that different response locations are discriminated in separate tasks even if they are performed in succession.

The results of the TC task sequence group are also in line with the predictions offered by the RDH. The SE was found in both the TC-EXPOSURE and the IGNG-POSTTEST task. In the TC-EXPOSURE task, the spatial codes used to discriminate the alternative responses were represented as such in WM (i.e., left-right codes to discriminate between responses) and the spatial stimulus codes would then activate the corresponding retrieval cues for those responses in WM resulting in the SE. Once participants completed the TC-EXPOSURE task and completed the IGNG-POSTTEST task in which the SE was found, supporting the argument that the response representations formed in the TC-EXPOSURE carried over to the IGNG-POSTTEST task. The original work by Ansorge and Wühr (2004, Experiment 4) examined the possibility of set effects – that is the carryover of spatial response representation from one task to the next. They found the SE in the Go/No-Go task when it was preceded by a TC task. The results of this task sequence group confirmed the predictions made by the RDH showing a SE in a Go/No-Go task when it is preceded by a task (TC) in which response alternatives are coded and discriminated according to their spatial features.
In contrast to the findings of Sebanz et al. (2003a; also see Study 1 and 2), the results from the JA task sequence group showed no difference in corresponding and non-corresponding trials in the JA-EXPOSURE task. This undoubtedly presented a challenge in our efforts to try and establish whether the SSE described by Sebanz et al. arises as a consequence of co-representation or because the task affords a context in which spatial labels are useful in discriminating between alternative responses. Should a SE be observed in a Go/No-Go task performed after a JA-EXPOSURE task, then the SSE may not be the result of task co-representation. According to a co-representation account, a SE would not be expected in a subsequent Go/No-Go task because there is no task sharing and thus no co-representation. To address this matter we manipulated the task sequence, as developed by Ansorge and Wühr (see Experiment 4, 2004), to determine whether a spatial response representation is formed in a JA task and prevails to produce a SE in a subsequent Go/No-Go task. We expected to observe a SE in the IGNG-POSTTEST task if the alternative responses in the JA-EXPOSURE task were discriminated and represented by spatial codes. These spatial response representations would then carry over to the IGNG-POSTTEST task. From the co-representation viewpoint, no SE should arise in the IGNG-POSTTEST task because there is no co-actor whose task can be represented. The results from the JA task showed completely different RT patterns from those described by Sebanz et al. (2003a; also see Study 1 and 2). While the SE was absent in the IGNG-BASELINE task as we predicted, the SSE was noticeably absent in the JA-EXPOSURE task which means that we did not replicate the basic findings of Sebanz and colleagues; specifically, RTs were no different for corresponding and non-corresponding trials in the JA task. The analysis of the IGNG-PRETEST and IGNG-POSTTEST tasks showed that behaviour was no different prior to or
after performing the JA-EXPOSURE task. It is impossible to interpret the preceding results since we did not find the SSE and cannot speak to what exactly was represented (response location or the co-actor’s task) and any possible carryover effect that that representation may have had (i.e., the absence or observation of a SE in the IGNG-POSTTEST task).

Once again, we did not replicate the SSE in either the JA-PRETEST or the JA-POSTTEST tasks\(^\text{16}\) in the JA-TC-JA task sequence group. We did show the expected effects (or lack thereof) in both the IGNG-BASELINE task (no SE) and the TC-EXPOSURE task (SE). We did note in the Result section that there was a trend towards a joint SE in the JA-POSTTEST task, which was of considerable interest because this would suggest that responses were spatially represented and stored in WM in the TC-EXPOSURE task and subsequently transferred to the JA-POSTTEST task. While the SSE was not shown in the JA-PRETEST task, which was inconsistent with previous findings (Sebanz et al. 2003a, 2005a, 2006b, 2007; Milanese et al., 2010, 2011; Tsai, et al., 2006; Welsh et al., 2007), it does offer support for our interpretation that the difference between non-corresponding and corresponding trials in the JA-POSTTEST task (15 ms)\(^\text{17}\) was driven by potential carryover effects from the preceding TC-EXPOSURE task. In fact, there was an opposite trend in the JA-PRETEST task with slightly faster responses to non-corresponding compared to corresponding stimuli for the JA-PRETEST task (446 ms vs. 451 ms).

Our failure to find the SSE in any of our JA tasks has made it impossible to resolve whether the effect is the result of discriminating and representing alternative responses according to their spatial features (RDH) or because participants were in fact co-representing.

\(^{16}\)Given the conflicting nature of our results, we decided to establish whether social symbols (i.e., pointing finger) enhance the SSE by replicating Sebanz et al.’s (2003a) experiment using the same type of social symbols. We have typically used non-social symbols (e.g., coloured asterisk) as experimental stimuli and have not always successfully found the SSE. See Study 5 for the details of this experiment.

\(^{17}\) Positive being faster RTs for the corresponding trials compared to the non-corresponding trials.
What was encouraging were our results for the TC task sequence group in which we confirmed the prediction made by the RDH. The SE was not observed in the IGNG-BASELINE or the IGNG-PRETEST task in which a single response was afforded and did not need to be spatially discriminated from an alternative response. As expected, the SE was observed in the TC-EXPOSURE task and the RDH was supported with our findings of a SE in the subsequent IGNG-POSTTEST task. Again, these results are in line with the argument that there was a carryover of spatial response representation from the TC-EXPOSURE to the IGNG-POSTTEST task (Ansorge & Wühr, 2004). Curiously, we are not the first to report null findings in a JA task. Wenke et al. (2011) devised a set of experiments to examine co-representation in which participants were required to make binary go/no-go responses instead of a single go/no-go response which is typically the case in task sharing studies. Using a variant of the Flanker task, they found no evidence for the co-representation of a co-actor’s S-R mapping which should create a response conflict. Guagnano et al. (2010) also failed to find a SSE when they investigated whether the presence of a co-actor provides a spatial reference point for the coding of alternative responses and how working space influences co-representation.

Since none of our predictions were substantiated, we are unable to confidently argue that the RDH is an alternative explanation for the SSE described by Sebanz and colleagues. What our study does offer is more supportive evidence that a SE can be observed in a Go/No-Go task when it is preceded by a task in which alternative responses are spatially discriminated (e.g., TC-EXPOSURE task). We also showed that the spatial response representations formed in a TC-EXPOSURE task had some degree of influence on

18 The task used was not complementary but rather two independent tasks were performed by participants.
performance in the JA-POSTTEST task with trends in the direction of a SE that were not apparent in the JA-PRETEST task.
5.5 Bridging Summary

In Study 4, we examined whether prior exposure with alternative response discrimination has an influence on responses in an Individual Go/No-Go task. We designed four unique task sequence groups to test whether a SE could be elicited in a Go/No-Go task. The SE was found in a Go/No-Go task when it was preceded by a 2-choice (TC) task which supports the prediction made by the response-discrimination hypothesis. In the case that participants were exposed to one stimulus-response (S-R) mapping in one Go/No-Go task followed by the opposite S-R mapping in the following Go/No-Go task, a SE was not observed. The one problem that we encountered in this study was our failure to replicate the social SE (SSE) in any of our joint action JA tasks, though the trend toward the SE was in the correct direction in one of the task sequence groups (i.e., faster RT on corresponding compared to non-corresponding trials). Therefore, we could not make a definite conclusion about the influence that exposure with alternative response discrimination may have had on a Go/No-Go task. Despite the absence of the SSE in the JA-PRETEST, after the exposure to the TC task, the JA-POSTTEST did reveal a trend toward a joint SE. This would suggest that perhaps responses were spatially discriminated, represented and stored in working memory in the TC-EXPOSURE task and this was consequently carried over to the JA-POSTTEST task.

Our failure to consistently replicate the SSE led us to question whether the social nature of the cueing stimuli (i.e., the pointing finger) used by Sebanz et al. (2003a) induced a larger SSE as it infers ‘your’ turn vs. ‘my’ turn in contrast to non-social stimuli (e.g., asterisks), which do not. In Study 5, we asked if social pointing stimuli enhance the SSE and we decided to carry out a replication of Sebanz et al.’s (2003a) original joint action experiment. Using the same social cuing stimuli, we continued to explore how the spatial
discrimination of response alternatives may induce a joint SE when performing two
independent tasks alongside another person in Study 6. We designed two novel joint action
tasks which were independent in nature. In the group condition, one participant performed
the typical Go/No-Go task while another participant pressed the same key or the opposite key
to initiate each trial. These tasks allowed us to examine whether the SE could be induced by
performing a task in which response alternatives could be discriminated.

Electroencephalographic (EEG) data were also recorded as a specific ERP component
called the P3 has been reported to reflect the processing of stimulus evaluation on go trials
and response inhibition on no-go trials. Modulations in the P3 amplitudes would provide us
with insight into how the processes involved in action planning and control may be different,
or similar for that matter, when performing a complementary task versus two independent
tasks alongside another person.
6 Chapter: Study 5 - The Power of the Pointing Finger: Do Social Pointing Stimuli Enhance the Social Simon Effect?

6.1 Introduction

Pointing is a means of human communication that serves to bring another’s attention to some potential source of information (e.g., event or object) and is deemed to be part of social activity (Tomasello, 1995). Sebanz and colleagues (2003a) used a pointing finger as the response cue and recognized that it could act as a turn-taking signal given its social nature. For example, on corresponding trials where the finger is pointing toward oneself, one would automatically infer that “it is my turn”. In contrast, on non-corresponding trials where the finger is pointing toward the other participant, one would infer that “it is their turn”. If participants form shared task representations when engaging in a complementary (turn-taking) task with another person then they predicted faster response times (RTs) when the finger pointed at them (corresponding trial) compared to when the finger pointed to the other participant (non-corresponding trial). If coordination with another participant is not necessary for the task (solo setting) then the Simon effect (SE) should be absent (cf. Hommel, 1996). Their results showed an interaction between social setting (solo vs. group) and compatibility supporting their argument that social context can shape mental processes in individuals.

In contrast to Sebanz et al. (2003a), we used coloured asterisks as experimental stimuli to explore the social Simon effect (SSE). There was no reason to believe that the SSE would be entirely eliminated by the type of cueing stimuli (i.e., non-social vs. social) used since the SSE is thought to arise on account of representing the stimulus-response rules and action plans of both those involved in the task. In the first three studies described in this
dissertation, non-social response cues (coloured asterisks) were used and we have not always been successful in observing the SSE despite having ensured that we replicated all other aspects of Sebanz et al.’s (2003a) experiment. This led us to raise the question of whether the social nature of the cueing stimuli (i.e., pointing finger) used by Sebanz et al. (2003a) induced a larger SSE as it infers ‘your’ turn vs. ‘my’ turn in contrast to non-social stimuli (e.g., asterisks), which do not\(^9\). To determine whether we could elicit similar differences in RTs, as observed by Sebanz et al. (2003a), and compare these results with those we observed using non-social stimuli, we set out to replicate their findings.

6.2 Methods

6.2.1 Participants

Sixteen participants completed the experiment (13 females; mean age 21.8 years, SD = 3.8 years). Only 1 participant was left-handed and all had normal or corrected-to-normal vision. The study was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent.

6.2.2 Apparatus

Stimulus presentation, the collection and recording of response times (RT) were carried out using E-Prime v2.0 software (Psychology Software Tools, Pittsburgh, PA). Stimuli were presented on a computer monitor (Dell 2408WFP 19”, 60 Hz refresh) centred on a 152 cm X 76 cm table. Participants were paired with a co-actor and sat approximately 45 cm from each

\[^9\] This question was also raised by Tsai et al. (2006) who reported a correspondence difference of 15.2 ms using coloured circles (red, green) in their JA condition.
other and 81 cm from the display. They were randomly assigned to one of two seats (left or right); seat position also determined response hand (i.e., left seat, left hand or right seat, right hand). Responses were collected with two response devices, one to left of the monitor and one to the right of the monitor. Each response device was placed approximately 51 cm from the centre of the monitor. Participants were instructed to use the index finger of their responding hand to execute their responses while keeping their inactive hand in their lap.

6.2.3 Stimuli

Stimuli were presented on the centre of the display on a black background. The fixation stimulus was a white cross (1 cm X 1 cm) and appeared on the screen for 800 ms. The imperative stimuli, which replaced the central fixation stimulus, were digital photographs of a human hand pointing to the left or the right with a ring (blue or yellow) on the index finger of the hand (see Figure 6.1), similar to those used by Sebanz et al. (2003a, 2005a). Stimuli were presented such that the ring always appeared at the centre of the display. The hand size was approximately 9.5 cm X 12 cm horizontally and vertically. The ring on the pointing finger was approximately 2.2 cm wide and 1.6 cm thick while the size of the pointing finger was approximately 8 cm X 2 cm. The imperative stimulus remained on the screen until a response was detected or 1250 ms elapsed.
6.2.4 Procedures

The tasks and procedures were identical to those described by Sebanz et al. (2003a) except for the following differences. First, we did not counterbalance the Individual Go/No-Go task (IGNG) and the 2-choice (TC) task. The tasks were always completed in the following order: IGNG, JA, TC. The reason for this was that studies have shown that a SE can be elicited in a Go/No-Go task if it is preceded by a TC task due to a carryover effect (see Ansorge & Wühr, 2004, 2009; Study 4). Second, we did not vary the context in the JA task. Sebanz and colleagues included a condition in which the co-actor sat passively beside the participant.

The experiment had a 3 Condition (IGNG, JA, TC) X 2 Correspondence (corresponding, non-corresponding) repeated measures design. Each condition consisted of a block of 10 practice trials and 160 experimental trials (2 target colours X 4 target positions X 20 repetitions, randomly presented).
6.3 Results

Figure 6.2 shows RT data for corresponding and non-corresponding trials under the three different conditions. If the wrong key was pressed then that trial was categorized as an error and the RT associated with it was eliminated from the data set. In addition, all trials in which the RTs were more than two standard deviations above or below the mean RT for that trial type and task were excluded from further analyses. Approximately 0% to 5% of the trials were removed from each participant’s data set based on these criteria. The mean RT for the TC task was calculated based only on the hand used to respond in the IGNG and the JA tasks.

RTs for correct responses were subjected to paired-sample t tests comparing corresponding and non-corresponding trials for the three different conditions. These tests revealed significant differences between corresponding (M = 426 ms, SD = 49.4) and non-corresponding (M = 443 ms, SD = 42.2) trials in the JA [t(15) = -3.56, p < 0.001, Cohen’s d = 0.38] condition and between corresponding (M = 493 ms, SD = 59.9) and non-corresponding (M = 524 ms, SD = 59.3) in the TC [t(15) = -2.91, p < 0.01, Cohen’s d = 0.52] condition. More specifically corresponding trials were faster in both the JA (426 ms) and TC (493 ms) conditions than the non-corresponding trials in both the JA (443 ms) and TC (524 ms) conditions. There was no significant SE in the IGNG condition [t(15) = -0.47, p = 0.64, Cohen’s d = 0.06] (corresponding: M = 449 ms, SD = 49.3; non-corresponding: M = 452 ms, SD = 47.9).
Figure 6.2  Mean RT on corresponding and non-corresponding trials for the IGNG, JA and TC conditions. The SEM on corresponding and non-corresponding trials, respectively, were 12 ms and 12 ms for the IGNG condition; 12 ms and 11 ms for the JA condition; and 15 ms and 15 ms for the TC condition.

6.4 Discussion

When engaging in a turn-taking task with another person, a manual gesture such as pointing can indicate whose turn should take place. We questioned whether the social nature of the response stimuli used by Sebanz et al. (2003a) may have played a role in inducing a larger SSE than what we have observed using non-social stimuli. If it is indeed the case that participants represent stimulus events irrespective of who is responsible for taking action
then the type of stimuli used should have no influence on the size of the effect. The overlap of the spatial dimension of the irrelevant stimulus (the direction of the pointing finger; the side of the display the asterisk appears) with the features used to represent the alternative responses (left, right) should automatically activate (i.e., prime) their corresponding responses (de Jong et al., 1994; Kornblum et al., 1990). In line with the SSE observed by Sebanz et al. (2003a), we too found a strong significant effect using social stimuli. As acknowledged by Sebanz et al. (2003b), the pointing finger is prone to being interpreted as a turn-taking signal. Thus, when the finger points to one’s self and a response is required, RTs should be faster than when the finger points away from them. From this standpoint, the predictions made by Sebanz and colleagues are sound but we are still left questioning whether the other’s task has been truly represented and integrated into one’s own action plans or if the implied “your turn” “my turn” quality of the social cuing stimuli (i.e., pointing finger) was simply prompting the responder.
Chapter: Study 6 - Spatial Response Discrimination Can Elicit a Joint Simon Effect in an Independent Task

7.1 Introduction

Traditionally, researchers have tested single participants when examining the cognitive and neural processes involved in action planning and control. The limiting factor to such an approach is that we are a social species. We engage in diverse interactive contexts and we can be motivated by a variety of different intentions which further complicate matters. Therefore it seems illogical not to examine how acting with another individual affects the attainment of task goals. A paradigm that has proven valuable in developing our understanding of social interaction is to investigate task sharing. Previous studies have examined how an individual’s performance is modulated while observing another’s action but by having two people share a common task it is possible to examine how performance is modulated while acting with another individual. What this line of research has uncovered is that in these joint task settings, even when coordination is not necessary to achieve the task goal, individuals will co-represent their co-actor’s task share as if it were their own (Sebanz et al., 2003a, 2005b, 2006a).

Shared representations can be described as a representation of a particular action that is activated not only in the individual performing it, but also in the individual who is interacting with them (Pezzulo, 2011). Evidence for this notion of a ‘shared representation’ comes from task sharing studies in which variants of the Simon task (e.g., Simon, 1990; Simon et al., 1970) have been used. In the Simon task, participants are usually asked to make left and right key press responses to a non-spatial stimulus feature (e.g., shape or colour).
Stimuli are presented on the left and right side of the screen and participants are told that the spatial location of the stimulus is irrelevant to the task. Results show that responses are faster when the stimulus position and response location correspond (i.e., right stimulus-right response) than when they do not (i.e., right stimulus-left response); this is referred to as the Simon effect (SE).

The SE is accounted for by so-called dual-route models. One of the more frequently cited is the dimensional overlap model (DOM) (Kornblum, 1994; Kornblum et al., 1990). This model assumes that stimulus features are processed along two parallel, but independent, response-activation pathways: an automatic (or unconditional) route and a controlled (or conditional) route. The unconditional route is assumed to be fast and automatically primes the response on the side that the stimulus is presented. For example, when a blue stimulus appears on the left side of the screen, the irrelevant information (stimulus location) is processed quickly along the unconditional route priming, and thus facilitating, a left side response, irrespective of instructions or stimulus identity. The level of activation will vary according to the amount of dimensional overlap between the stimulus and response sets: the more overlap, the greater the benefit for corresponding responses versus non-corresponding responses. The conditional route is often described as being slow and under intentional control; responses are selected according to task instructions. In the case that a left response has been assigned to the blue stimulus then a left response is selected. Facilitation, or interference, arises because both routes converge at the response selection stage. When the conditional and unconditional routes activate the same response (corresponding trials), response times are fast and fewer errors are made; this process facilitates efficient performance. Interference results when the two routes activate different responses (non-
corresponding trials). This conflict must be resolved before the correct response can be executed and as a consequence RTs are delayed and more prone to error.

One condition in which the standard finding of a SE is not observed (e.g., Ansorge & Wühr, 2004, 2009) or is considerably reduced (e.g., Callan et al., 1974) is in Go/No-Go tasks (cf. Hommel, 1996). In this task, participants are assigned a single response and instructed to respond to one stimulus type and to inhibit their response to another stimulus type. Based on comparisons made using Donders’ (1969) three RT paradigms, Callan et al. (1974) concluded the requirements at the response selection level were reduced in a Go/No-Go task compared to the conventional 2-choice RT task and this gave rise to a diminished SE. This exception to the standard finding of a SE has proven valuable to task sharing studies investigating how knowledge of another person’s task can influence one’s own action planning and control (Sebanz et al., 2003a).

When two individuals share a task do they co-represent each other’s task? To answer this question, Sebanz et al. (2003a) carried out a series of behavioural experiments in which performance was compared under three different social conditions using a go/no-go variant of the Simon task. Participants were presented with pictures of a human hand pointing either to the left, the middle, or the right with a red or green ring on the index finger. The instructions were to respond to the colour of the ring with a key press response as quick and as accurately as possible; the direction of the hand was irrelevant to the task. In the 2-choice (TC) condition, participants performed the standard Simon task in which they sat alone making binary choice responses based on the colour of the stimulus (e.g. left response-red, right response-green). In the Individual Go/No-Go (IGNG) condition, participants sat alone in one of two chairs positioned side-by-side, making a single response to one of two stimulus
colours which meant they may have to execute (go trials) or withhold (no-go trials) responses (e.g., left response-red, ignore-green). Finally, in the Joint Go/No-Go (JA) condition, a co-actor sat in the empty chair alongside the participant and together they engaged in a complementary Go/No-Go task (e.g., participant: left response-red, co-actor: right response-green).

An analysis of the data revealed the standard SE in the TC task replicating previous findings (De Jong et al., 1994; Kornblum et al., 1990; Lu & Proctor, 1995; Prinz, 1990). In the IGNG task, a substantially reduced, non-significant SE was found. Interestingly, when participants completed the JA task, the SE re-emerged despite the fact that participants were still performing the same task as in the IGNG condition but with a co-actor who was responding to other stimuli with the alternative response. According to Sebanz et al. (2003a), the shared-task effect occurs because participants have formed a shared representation of the co-actor’s task which affected their own action scheme. A number of studies have since replicated some variation of the social Simon effect (SSE) (e.g., Tsai et al., 2006; Vlainic et al., 2010; Welsh, 2009) and explored necessary preconditions for the formation of shared representations (e.g., Atmaca et al., 2008; Ruys & Aarts, 2010; Tsai et al., 2008; Welsh et al., 2007) but the notion of co-representation is now being challenged and alternative explanations for this so-called ‘social’ SE are being proposed.

The spatial reference hypothesis refers to the spatial coding of personal location in the joint action setting which may elicit the SSE (Welsh, 2009). Recall the experimental setup used in the task sharing paradigm. Participants were sitting alongside a co-actor which could establish the coding of the two available responses as left and right. In the IGNG task, the only available response would not be spatially coded. Guagnano et al. (2010) found the SSE
when two participants performed independent tasks side-by-side in peripersonal space but not when the co-actor was beyond arm-reach (extrapersonal space). The observation of the SSE in this context cannot be due to co-representation since participants each performed their own simple RT task as opposed to two Go/No-Go tasks. Guagnano et al. went on to suggest that the presence of the co-actor acted as a potential spatial reference point which established a condition in which the two available responses were spatially coded. Consequently, when the distance between the participants extended beyond arm’s reach, the SSE disappeared (see results of Tsai et al., 2008 for an example of when a complementary task was used but also see Welsh et al., 2007). When participants perform with a co-actor outside their peripersonal space, responses are no longer coded in reference to the spatial location of the other. Granted, the spatial response coding account was supported by these findings in the context of performing independent tasks rather than a complementary task. However, recent studies continue to explore how the saliency of an event or action can provide a spatial reference for coding such as the work of Dolk et al. (2011) who used the rubber hand illusion to induce referential coding and Dittrich et al. (2012) who manipulated the saliency of spatial response dimensions (see Study 3).

The aim of the present study was to further examine whether the SSE is primarily driven by spatial response coding or co-representation. The response discrimination hypothesis (RDH) explains variations of the SE (Ansorge & Wühr, 2004, 2009) and provides us with a framework to establish whether spatially discriminated responses represented in working memory (WM) can account for the SSE observed in task sharing studies. Ansorge and Wühr (2004, Experiment 5) demonstrated that the SE could be elicited in a Go/No-Go task by simply creating a context in which it would be useful to discriminate alternative
responses according to their spatial location. To do so, they designed two different conditions which manipulated the spatial relation between the key that was used to initiate the trial and the key that was used to perform a Go/No-Go task. In one condition, participants were instructed to press a single response key not only to initiate each trial but to also respond to the target. In the other condition, participants were instructed to press one response key to initiate each trial and to press an alternative response key to respond to the target. While the SE was observed when two spatially defined response keys were used (the latter condition), it was absent when the task only entailed the use of a single response (the former condition).

The RDH asserts that when spatial response features are used to discriminate between alternative responses then those responses will be represented as such in WM. In turn, the SE will arise in a Go/No-Go task because these task specific response codes overlap with the stimulus location and a direct activation of the corresponding response is possible. If the response alternatives in a given task situation are differentiated according to a particular response parameter, in this case response location (left, right) then perhaps this is what is giving rise to the effect described by Sebanz et al. (2003a). Therefore, we ask whether a SSE can be observed when two participants are performing independent tasks in which alternative responses are presented at different spatial locations.

To address this matter, we investigated the SSE under conditions that amalgamated aspects of the tasks used by Ansorge and Wühr (2004, Experiment 5) and Sebanz et al. (2003a, Experiment 1). All participants performed the IGNG task followed by one of three tasks in a group setting: Joint Action (JA), Joint Opposite-Key (JOK), Joint Same-Key (JSK). The JA task will be a replication of Sebanz et al.’s (2003a) first experiment using the same basic paradigm. The two novel joint tasks that we designed had two participants performing
two independent tasks alongside each other. The role of the co-actor was to initiate each trial for the participant by pressing the same key as the participant (JSK task) or the opposite key to the one being used by the participant (JOK task). The participant performed the same Go/No-Go task as they did in the IGNG task. If participants discriminate between the two response alternatives on the basis of spatial position as afforded by the task (JOK task) then we expect to find the SE. In contrast, the SE should be absent when there is only a single response (JSK task) that does not necessitate it to be spatially discriminated. We expect to replicate the SSE in the JA task and the absence of a SE in the IGNG task as observed by Sebanz et al. (2003a). It is important to make clear that our intention is not to necessarily disprove the notion of co-representation but rather to demonstrate that it is possible to observe a SE in a Go/No-Go task in a social context without necessarily reflecting the co-representation of another individual.

We also evaluated whether action planning and inhibitory control differ, if at all, when performing an independent as opposed to a complementary task. To do so, we evaluated event-related potentials (ERPs), more specifically the P3 component which has been shown to modulate in the Go/No-Go condition (Bokura et al., 2001). The P3 component is a positive waveform that peaks between 300 and 600 ms and its latency is thought to reflect stimulus evaluation time while its amplitude has been attributed to the amount of processing capacities allocated to the stimulus (see review by Kok, 1990). The P3 has a maximum at centroparietal sites on go trials and at frontocentral sites on no-go trials (Fallgatter et al., 1999; Fallgatter & Strik, 1999). Studies examining the effects of stimulus-response (S-R) compatibility on P3 amplitude have offered mixed findings with some identifying decrements in the P3 amplitude in non-corresponding trials compared to
corresponding trials (Christensen et al., 1996; McCarthy & Donchin, 1981; Pfefferbaum et al., 1986), others have found larger P3s to non-corresponding than corresponding stimuli (Ragot & Fiori, 1994) and some have shown no difference at all (Ragot, 1984; Ragot & Renault, 1981). These reported differences in P3 amplitude have been ascribed to interference at the perceptual-encoding stage (Hasbroucq & Guiard, 1991) in which the processing of non-corresponding features (e.g., left stimulus, right response) is compromised and due to response selection conflict (Zhou et al., 2004; Valle-Inclán, 1996).

The go/no-go effects on P3 amplitudes are more frequently discussed with respect to response inhibition (Bokura et al., 2001; Falkenstein et al. 1995; Roberts et al., 1994; Pfefferbaum et al., 1985). Response inhibition can be defined as the act of withholding or ceasing a behavioural response and is considered to be governed by a cognitive inhibitory process (Logan et al., 1984). No-go trials elicit a larger P3 component relative to go trials at the frontal midline (Fz) and central midline (Cz) electrodes and have been observed in various studies using visual stimuli (Eimer, 1993; Falkenstein et al., 1995; Roberts et al., 1994; Simson et al., 1977). The aforementioned go/no-go effects on P3 amplitudes have already been exploited in studies examining co-representation to explore action planning and control (Sebanz et al., 2006b; Tsai et al., 2006).

To strengthen their argument that individuals co-represent in the joint condition, Sebanz et al. (2006b) measured the ERPs of participants when they performed the Go/No-Go task alone and with a co-actor. They predicted that if co-representation was taking place then the Go P3 amplitude should be modulated when a stimulus referred to the co-actor’s response

---

20 Note that the S-R compatibility tasks used in these studies varied from semantic to spatial. Only the studies by Ragot (1984) and Ragot & Renault (1981) used a Simon task.
(group condition, non-corresponding trial) compared to when the stimulus did not refer to anyone’s response (solo condition, non-corresponding trial). Indeed, a larger Go P3 peak amplitude was observed in non-corresponding trials for those in the group condition compared to the solo condition. This finding supports the idea that in the group condition, participants equally represented both response alternatives. They also demonstrated increased inhibitory control reporting a significantly larger No-Go P3 amplitude in the group condition compared to the solo condition due to the co-actor’s response being represented. While we anticipate replicating Sebanz et al.’s (2006b) findings, we make the following predictions about the outcome of our two novel independent joint tasks. In the JOK task, we expect to observe a similar pattern of differences in the P3 amplitude for both go and no-go trials across both the individual and joint conditions as described by Sebanz et al. (2006b). Just as modulations in the P3 component were interpreted to reflect that stimuli were evaluated differently for the purpose of action planning in the group condition and that increased inhibitory control was necessary when performing the task with another person, we suspected that similar processes would be taking place when performing the independent tasks we developed. In the JOK task, participants should be inclined to use spatial codes to represent alternative responses because the start and go responses are on opposite sides (i.e., left-right). We would expect that this spatial coding of responses under these circumstances should have a similar impact on action planning and control because the targets are on the same spatial axis along which the alternative responses were discriminated which we suspect will give rise to a SE as observed by Ansorge and Wühr (2004, Experiment 5). In the JSK task, we predict that there will be no difference in the P3 amplitudes across the solo and group
condition because there is only a single response and as a result the evaluation of stimuli and the inhibition of responses should not be affected by non-corresponding stimuli.

7.2 Methods

7.2.1 Participants

Forty-two participants completed the experiment (23 females; mean age 24.3 years, SD = 4.2 years). Only 3 participants were left-handed and all had normal or corrected-to-normal vision. The study was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent.

7.2.2 Apparatus

Stimulus presentation, the collection and recording of response times (RTs) were carried out using E-Prime v2.0 software (Psychology Software Tools, Pittsburgh, PA). Stimuli were presented on a computer monitor (Dell 2408WFP 19”, 60 Hz refresh) centred on a 152 cm X 76 cm table. The seating arrangement was such that participants sat approximately 45 cm from each other and 81 cm from the display. They were randomly assigned to one of two seats (left or right) which also determined what response hand they would be using (i.e., left seat-left hand, right seat-right hand). Responses were collected with two response devices, one to left of the monitor and one to the right of the monitor. Each response device was placed approximately 51 cm from the centre of the monitor. Participants were instructed to

21 Of the forty-two participants who completed the experiment only thirty participants yielded sufficiently clean and artifact-free EEG data to be submitted for analysis. In total there were ten participants in each of the three groups.
use the index finger of their responding hand to execute their responses while keeping their inactive hand in their lap.

7.2.3  Stimuli

Stimuli were presented at the centre of the display on a black background. The blinking cue was a small grey cross (0.5 cm X 0.5 cm) presented at the centre of the display for 1500 ms and was replaced by the fixation stimulus which consisted of a white cross (1 cm X 1 cm) for 800ms. The imperative stimuli, which replaced the central fixation stimulus, were digital photographs of a human hand pointing to the left or the right with a blue or yellow ring on the index finger, similar to those used by Sebanz et al. (2003a, 2006b). Stimuli were presented such that the ring always appeared at the centre of the display. The hand size was approximately 9.5 cm X 12 cm, horizontally and vertically. The ring on the pointing finger was approximately 2.2 cm wide and 1.6 cm thick while the size of the pointing finger was approximately 8 cm X 2 cm. The stimulus remained on display until a response was made or 1250 ms passed. When participants made an error, a feedback message was presented for 750 ms stating that an incorrect response was detected.

7.2.4  Procedures

Upon arrival for testing, participants were randomly assigned to one of two seating positions. To prepare the skin prior to application of the electrooculogram (EOG) and electromyogram (EMG) electrodes and to decrease electrical impedance, the skin was cleaned with 70% ethyl alcohol pads. Surface electrodes (Biotrace bioadhesive rectangular, cloth-backed neonatal ECG electrodes (Ag/AgCl)) were placed above and below the right eye to measure vertical
eye movements (vEOG) as well as on the left and right outer canthi to measure horizontal eye movements (hEOG). After EOG electrode placement, the EEG cap was placed on the participant’s head and the distances between the nasium and the occipital bone, and between the mastoid processes, were measured to identify the top centre (Cz) of the head; this ensured the fitting of EEG electrodes to the scalp of the participant. A small sterile syringe with a blunt-tipped needle was filled with conductive gel and inserted into each electrode. The syringe was used to part the hair and gently abrade the scalp to remove any dead skin; each electrode was subsequently filled with a small amount of gel. Once the criterion impedance (< 10 kΩ) was reached, testing could proceed.

The participants were randomly assigned to the JA task group, the JOK task group or the JSK task group and given verbal and visual instructions describing their tasks. The participants in the JA task group were told that the first task they would complete was the IGNG task (see Figure 7.1A). Depending on which seat they were sitting in, they were assigned a single response key to make their responses. They were told that they would first see a small grey fixation cross during which time they could blink their eyes should they choose. The experimenter stressed to participants that it was important that they refrain from blinking as this would contaminate that particular EEG epoch. Following the cue for eye blinking, a larger white cross would replace it and participants were asked to maintain fixation at the centre of the screen. The target stimulus would then appear and participants were instructed to respond according to the colour of the ring on the finger. Should the colour of the ring on the finger not match their assigned stimulus colour, they were told to refrain from making any response. Feedback would be provided if an error was detected but if not a blank screen would appear and then the trial starting with the cue for eye blinking would be
presented. After having completed the IGNG task, the co-actor was introduced to the participant and sat in the once empty chair beside the participant to perform the JA task (see Figure 7.1C). The co-actor was instructed to place their index finger of their responding hand on the once unoccupied response device. For example, if the participant was sitting in the left seat then the co-actor would sit in the right seat and use their right hand to respond. Once more, instructions were given both verbally by the experimenter and visually on the display at the beginning of the task. The participant was instructed to perform the task as they had done in the solo condition, to respond “as fast and as accurately as possible” to their designated target stimulus (e.g., blue ring) and ignore the other one (e.g., yellow ring). The co-actor was then instructed to respond to the other target stimulus (e.g., yellow ring) “as fast and as accurately as possible” while ignoring the other one (e.g., blue ring). The sequence of events in a trial was no different between the IGNG and the JA tasks (see Figure 7.2 for temporal sequence of events in a trial).
Figure 7.1  Experimental setup. (A) A schematic of the solo condition in which participants performed the IGNG task. (B) A schematic of the group condition in which participants performed alongside the co-actor who initiated each trial using the same response key (JSK task). (C) A schematic of the group condition in which participants performed alongside the co-actor who either initiated each trial using the opposite response key (JOK task) or performed the complementary part of the Simon task (JA task).
Figure 7.2  Temporal sequence of events in a trial for the JA, JOK and JSK tasks. The one difference in the JOK and the JSK tasks was the addition of a cue to start presented at the beginning of the trial.

The sequence of events in a trial was slightly different for the Joint Opposite-Key (JOK) and the Joint Same-Key (JSK) groups in which the role of the co-actor was to initiate each trial for the participant. Participants in both the JOK and JSK groups were given the exact same set of instruction for the IGNG task as those in the JA group. Once the IGNG task was complete, the co-actor was introduced to the participant and the experimenter described the next task. While the goal of the participant remained the same, respond to one specified ring colour while ignoring the other one, the role the co-actor played was altered. Rather than performing a turn taking task with the participant (JA group), the role of the co-actor in both the JOK and JSK groups was to simply initiate each trial for the participant; this defining feature was thought to introduce an independent quality to the task. At the beginning of the trial, the word “Start!” would appear at the centre of the display which cued the co-actor to
press their response to key to initiate the trial for the participant. In the JOK group, the co-actor pressed one key (e.g., left response) to start the trial while the participant pressed the key on the opposite side (e.g., right response) to respond to the go signal. In the JSK, the co-actor pressed the same response key (e.g. left response) to start the trial that the participant used to respond to the go signal (e.g., left response) (see Figure 7.2 for sequence of events in a trial for the JOK or JSK tasks).

Testing sessions lasted approximately two hours which included EEG preparation and the completion of two tasks. Participants completed one block of 10 practice trials followed by 20 blocks of 20 trials for both the solo condition and the group condition. Each block of 20 trials consisted of 5 random presentations of the yellow or blue ring on the leftward or rightward pointing finger. It is important to note that participants responded to the same colour with the same hand for both the solo and group conditions to avoid the need for remapping. The task under the solo condition (i.e., IGNG) was always performed prior to the task under the group condition (i.e., JA, JSK or JOK task) in efforts to prevent potential carryover effects (Ansorge & Wühr, 2004, 2009; Hommel, 1996). Emphasis was made on responding as quickly as possible since RT was the measure of interest.

Electrophysiological Recording

EEG was recorded using the ASA-Lab system with REFA-72 DC amplifier (TMS International BV) and WaveGuard cap (ANT Enschede, The Netherlands) with 64 integrated Ag/AGCl electrodes arranged in the 10/5 International System. EEG data, however, were only collected from 32 scalp electrode sites (FP1, FPz, FP2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, M1, T7, C3, Cz, C4, T8, M2, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, POz, O1, O2).

Note that EEG data were only collected from the participant.
Oz, O2) using ASA software (ANT Inc., the Netherlands). EEG signals were referenced to an average reference of all EEG electrodes. Scalp electrode impedences were kept at or below 10 kΩ. The electrooculogram (EOG) was recorded with a bipolar montage. Both EEG and EOG were recorded continuously throughout the testing session, sampled at 500 Hz. The ground was positioned at AFz. The EEG channels were re-referenced offline to the average of the two mastoid signals.

**ERP Waveform Analysis**

ERP averaging was performed offline in ASA (Version 4.5). ERPs were time-locked to the onset of the stimulus with a time window from -200 to 1000 ms. Prior to the derivation of the stimulus-locked ERP, the continuous EEG data were low pass filtered at 30 Hz (12 dB/oct). Artifact events (eye blinks) were marked in order to eliminate these trials from further analysis. In addition, an artifact detection parameter was set from -100 to 100 µV to eliminate any trials for which there were muscle potentials. Therefore, only artifact-free trials were averaged to create the ERP separately for each condition and for each subject. Finally, any particular ERP epoch for which the RT fell outside 2 SD of a condition mean was also rejected. Baseline correction (duration = 0.2 s) was performed after the trial averaging process. ERP waveforms were subsequently low pass filtered at 8 Hz prior to calculating mean ERP amplitudes (described later).

### 7.3 Results

The data of twelve participants were excluded from both the behavioural and electrophysiological analysis because of epochs with extreme eye movements, technical problems during EEG recording and too few good EEG segments.
7.3.1 Behavioural Results

Trials were excluded from analysis if an incorrect response or the absence of a response was detected. Responses were organized according to stimulus colour (orange or blue) and direction of pointing finger (left or right). Any RTs that were two standard deviations above or below the mean for each trial type within a condition (solo or group) were also eliminated from further analysis. The mean error rate across all IGNG tasks was 0.2%. In the JOINT condition, it was 1.8% in the JA task, 0.1% in the JSK task and 1.3% in the JOK task.

Table 7.1 (also see Figure 7.3) shows the mean RT (go trials), standard error of the mean (SEM) and the correspondence effect for the solo and group condition in each group. Paired-sample $t$ tests were used to compare corresponding and non-corresponding trials in the solo and group condition for each group (JA, JOK, JSK). The SSE could be seen in the difference between corresponding and non-corresponding trials in the JA group; a paired-sample $t$-test showed that corresponding ($M = 395$ ms, $SD = 39.4$) trials were faster than non-corresponding ($M = 415$ ms, $SD = 39.7$) trials $[t(9) = -4.12, p < 0.01, \text{Cohen’s} \ d = 0.51]$ under the group condition. We also found that in the JOK group corresponding ($M = 444$ ms, $SD = 57.8$) trials were significantly faster than non-corresponding ($M = 450$ ms, $SD = 58.1$) trials $[t(9) = -2.33, p = 0.04, \text{Cohen’s} \ d = 0.11]$ under the group condition when the co-actor was pressing the opposite key to the participant to initiate the trials. There was no significant difference between corresponding ($M = 406$ ms, $SD = 43.9$) and non-corresponding ($M = 405$ ms, $SD = 32.2$) trials in the JSK group under the group condition $[t(9) = 0.29, p = 0.78, \text{Cohen’s} \ d = 0.04]$. Under the solo condition, there was no significant difference between corresponding ($M = 418$ ms, $SD = 34.0$) and non-corresponding ($M = 426$ ms, $SD = 48.6$) trials for the JA or the JOK groups (corresponding: ($M = 436$ ms, $SD = 54.2$); non-
corresponding: (M = 432 ms, SD = 49.1). Analysis of the solo condition did reveal that corresponding (M = 410 ms, SD = 37.8) trials were significantly slower than non-corresponding (M = 403 ms, SD = 38.2) trials \[t(9) = 2.41, \ p = 0.04, \ \text{Cohen’s } d = 0.19\], showing a negative SE for the JSK group.

<table>
<thead>
<tr>
<th></th>
<th>JA SOLO</th>
<th>JA GROUP</th>
<th>JOK SOLO</th>
<th>JOK GROUP</th>
<th>JSK SOLO</th>
<th>JSK GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>C RT (ms)</td>
<td>417.9</td>
<td>426.1</td>
<td>394.9</td>
<td>415.1</td>
<td>436.0</td>
<td>432.3</td>
</tr>
<tr>
<td>NC RT (ms)</td>
<td>436.0</td>
<td>432.3</td>
<td>444.1</td>
<td>450.3</td>
<td>410.4</td>
<td>403.2</td>
</tr>
<tr>
<td>SEM</td>
<td>10.7</td>
<td>15.4</td>
<td>12.5</td>
<td>12.6</td>
<td>17.1</td>
<td>15.5</td>
</tr>
<tr>
<td>Correspondence*</td>
<td>8.2</td>
<td>20.2</td>
<td>-3.7</td>
<td>6.2</td>
<td>-7.2</td>
<td>-1.5</td>
</tr>
</tbody>
</table>

Table 7.1 Mean RT (go trials) on Corresponding (C) and Non-Corresponding (NC) trials in the solo and group conditions for the three groups (JA, JOK, JSK). *The correspondence effect = RT$_{\text{non-corresponding}}$ - RT$_{\text{corresponding}}$. 
Figure 7.3  Mean RT on corresponding and non-corresponding trials for the JA, JOK and JSK groups. The SEM on corresponding and non-corresponding trials for the solo and group conditions, respectively, were 11 ms, 15 ms, 13 ms and 13 ms for the JA group; 17 ms, 16 ms, 18 ms and 18 ms for the JOK group; 12 ms, 12 ms, 14 ms, 10 ms for the JSK group.

7.3.2 Electrophysiological Data

P3 amplitudes were calculated as a mean amplitude over a 200 ms window. To define the temporal window, we first derived a grand ERP average across all participants for each unique trial type (go corresponding, go non-corresponding, no-go corresponding and no-go non-corresponding) for both the solo and group conditions. We then identified the time at which the P3 peak was reached at the parietal midline electrode (Pz) site in the grand average. Once we identified the time at which this Pz maximum amplitude was achieved, we
formulated a 200 ms time window around it (i.e., \( \pm 100 \) ms) and subsequently calculated the mean P3 amplitude separately for each participant under each condition. These values were then averaged across all participants to derive our overall mean P3 amplitudes. Our analysis was based on mean amplitudes over the midline electrodes (Fz, Cz, Pz). We restricted our analyses to the midline electrodes as we were not particularly interested in factors such as laterality at this time. We derived the mean P3 amplitudes in the three groups (JA, JOK, JSK) for the go and no-go trials separately. A 2 Condition (solo, group) X 3 Electrode (Fz, Cz, Pz) X 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA was conducted for each set of data.
7.3.2.1 Go and No-Go P3 Components for the JA Group

Figure 7.4 Grand averages showing Go P3 (A) and No-Go P3 (B) for the JA group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.

Figure 7.4A shows the grand averages on go trials at the midline electrodes, locked to stimulus onset for the JA group. Visual inspection shows larger P3 amplitudes at the central and parietal sites compared to the frontal site. The P3 for non-corresponding trials appears to be smaller in amplitude in the group condition than the solo condition at both Cz and Pz, which contradicts the findings of Sebanz et al. (2006b) who found a smaller P3 complex in
the solo condition at both Fz and Cz compared to the group condition. We also note that there 
does not appear to be a distinct difference between corresponding and non-corresponding 
trials.

We analyzed the mean P3 amplitudes for Go in the JA group (see Table 7.2). There 
was no significant main effect of Correspondence \[ F(1, 9) = 2.81, p = 0.13 \] while Condition 
showed a trend toward significance \[ F(1, 9) = 3.96, p = 0.08 \] with smaller Go P3 amplitudes 
in the group compared to the solo condition. Some studies have reported a larger Go P3 
amplitude on corresponding trials compared to non-corresponding trials; however, others 
have presented evidence of the opposite or even no difference at all as described earlier. P3 
amplitudes differed across electrodes \( F(2, 18) = 44.53, p < 0.01 \) and a post hoc comparison 
\((\text{Tukey’s HSD}, p < 0.05)\) showed that the Go P3 amplitudes were larger at both the central 
\((\text{Cz: 12.91} \mu\text{V})\) and parietal electrode sites \((\text{Pz: 16.45} \mu\text{V})\) compared to the frontal electrode 
site \((\text{Fz: 3.17} \mu\text{V})\). These findings are in accordance with other studies that have found an 
anterior minimum \((\text{e.g., Tekok-Kilic et al., 2001; Polich, 1993})\). A significant Condition \(X\) 
Electrode interaction was found \( F(2, 18) = 6.37, p = 0.01 \). Post hoc analysis showed larger 
Go P3 amplitudes at both centroparietal sites for the solo condition \((\text{Cz: 14.59} \mu\text{V}, \text{Pz: 18.72} \mu\text{V})\) compared to the group condition \((\text{Cz: 11.25} \mu\text{V}, \text{Pz: 14.18} \mu\text{V})\).
Table 7.2  Mean P3 amplitudes for the JA group. The mean amplitudes and mean standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding) for the JA group.

Figure 7.4B shows the grand averages on no-go trials at the midline electrodes, locked to stimulus onset for the JA group. Visual inspection revealed a smaller positivity in the group condition vs. the solo condition which increases from the frontal to the parietal electrode. The No-Go P3 component is largest over the central and posterior regions. Comparing the waveforms across the go and no-go trials (Figure 7.4A and B), the peak P3 amplitude is larger at Fz in the no-go trials compared to go trials and gets progressively
smaller moving posteriorly. This exemplifies the No-Go anteriorization in which the centroid of the No-Go P3 positivity appears to be located more anterior than the Go P3 (Fallgatter et al., 1997).

Analysis of the No-Go P3 revealed no main effect of Correspondence \[F(1, 9) = 0.38, p = 0.55\]. The solo condition showed a trend toward a larger No-Go P3 amplitude compared to the group condition but Condition did not reach statistical significance \[F(1, 9) = 4.07, p = 0.07\]. The main effect for Electrode was significant \[F(2, 18) = 23.59, p < 0.01\] showing that No-Go P3s were smaller frontally than centrally and parietally (Fz: 4.26 µV, Cz: 12.79 µV, Pz: 11.76 µV). Two significant interactions were found, one between Condition X Electrode \[F(2, 18) = 6.05, p = 0.01\] and Electrode X Correspondence \[F(2, 18) = 5.85, p = 0.01\]. Post hoc analysis showed that No-Go P3 amplitude was smaller at the central and parietal sites in the group condition compared to the solo condition. In addition, on both corresponding and non-corresponding trials, the No-Go P3 amplitude was smaller at Fz electrode compared to the Cz and Pz electrodes. An examination of the grand averages for no-go trials (see Figure 7.4B) shows that the amplitude is smaller in the group condition in contrast to the solo condition which is in line with the main effect of Condition approaching significance. This is, however, at odds with Sebanz et al.’s (2006b) claim that in the group condition, increased response inhibition, indicated by larger No-Go P3 amplitudes, would be necessary as co-representation should have taken place.
7.3.2.2 Go and No-Go P3 Components for the JOK Group

Figure 7.5  Grand averages showing Go P3 (A) and No-Go P3 (B) for the JOK group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.

Figure 7.5A shows the grand averages on go trials at the midline electrodes, locked to stimulus onset for the JOK group. The grand averages for the go trials showed similar patterns to those in the JA condition (see Figure 7.4A). By visual inspection we can see that the Go P3 maximum is located more posteriorly (i.e., Cz and Pz). Also note that the grand
average waveform for the group condition appears smaller than the solo condition at both the central and posterior sites.

We analysed the mean P3 amplitudes for go trials in the JOK group (see Table 7.3). In the go trials, there was a main effect for Electrode [$F(2, 18) = 40.98, p < 0.001$]. Post hoc analysis showed that the P3 amplitude was significantly larger at the central (Cz: 10.54 µV) and parietal (Pz: 15.75 µV) electrode sites compared to the frontal (Fz: 1.36 µV) electrode site. There was no significant main effect of Condition [$F(1, 9) = 1.82, p = 0.21$] or Correspondence [$F(1, 9) = 0.84, p = 0.38$]. A significant interaction between Condition X Electrode [$F(2, 18) = 5.46, p < 0.01$] was revealed. Similar to the pattern of results in the JA group, the post hoc analysis showed a smaller centroparietal maximum in the group condition (Cz: 11.72 µV, Pz: 17.40 µV) compared to the solo condition (Cz: 9.36 µV, Pz: 14.10 µV).
Table 7.3  Mean P3 amplitudes for the JOK group. The mean amplitudes and standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding).

<table>
<thead>
<tr>
<th></th>
<th>GO TRIALS</th>
<th>NO-GO TRIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GROUP</td>
<td>SOLO</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>NC</td>
</tr>
<tr>
<td>Fz</td>
<td>0.89 (5.94)</td>
<td>1.09 (5.44)</td>
</tr>
<tr>
<td>Cz</td>
<td>9.59 (7.83)</td>
<td>9.13 (7.62)</td>
</tr>
<tr>
<td>Pz</td>
<td>14.55 (7.62)</td>
<td>13.64 (6.63)</td>
</tr>
<tr>
<td></td>
<td>3.53 (4.97)</td>
<td>3.15 (4.45)</td>
</tr>
<tr>
<td></td>
<td>8.58 (7.37)</td>
<td>8.01 (6.70)</td>
</tr>
<tr>
<td></td>
<td>7.78 (5.70)</td>
<td>8.12 (6.27)</td>
</tr>
</tbody>
</table>

Figure 7.5B shows the grand averages on no-go trials at the midline electrodes, locked to stimulus onset for the JOK group. Once more, the grand averages for the no-go trials showed similar patterns to those in the JA condition (see Figure 7.4B). The waveform in the group condition appears to be smaller in amplitude than in the solo condition with that difference increasing posteriorly. Yet again, going from the frontal site to the more posterior sites, the No-Go P3 amplitude is larger. A comparison between the go trials and the no-go...
trials (Figure 7.5A and B) reveals larger P3 amplitudes at Fz on no-go trials that gets smaller at Cz and Pz whereas the P3 amplitude is more pronounced at Cz and Pz on go trials.

The No-Go P3 amplitude showed a main effect for Electrode \([F(2, 18) = 20.51, p < 0.001]\). The amplitude was smaller at the frontal (Fz: 3.84 µV) electrode site compared to both the central (Cz: 9.65 µV) and parietal (Pz: 9.93 µV) electrode sites. There were no other main effects or interactions which attained significance.

7.3.2.3 Go and No-Go P3 Components for the JSK Group

![Figure 7.6](image)

**Figure 7.6** Grand averages showing Go P3 (A) and No-Go P3 (B) for the JSK group. This figure shows the electrophysiological response at midline to corresponding and non-corresponding trials in the solo and group condition.
Figure 7.6A shows the grand averages on go trials at the midline electrodes, locked to stimulus onset for the JSK group. Upon visual inspection of the grand averages, the differences between the solo and group conditions described in the JA and JOK group were not evident in the JSK group. The mean amplitude for the group condition appeared to be slightly larger in the solo condition at Fz, but little difference was seen at Cz and Pz.

We carried out the analysis of the mean P3 amplitudes for go trials in the JSK group (see Table 3.4). The P3 amplitude was larger at the central and parietal electrode sites than at the frontal site (Fz: 2.61 µV, Cz: 12.44 µV, Pz: 16.02 µV) on go trials \( [F(2, 18) = 23.03, p < 0.001] \). The effects of Condition \( [F(1, 9) = 0.94, p = 0.36] \) and Correspondence \( [F(1, 9) = 0.50, p = 0.50] \) were not significant. No significant interactions were found.
Table 7.4  Mean P3 amplitudes for the JSK group. The mean amplitudes and standard deviations (in microvolts) are shown for trial type (go and no-go), condition (solo and group) and correspondence (corresponding and non-corresponding).

Figure 7.6B shows the grand averages on no-go trials at the midline electrodes, locked to stimulus onset for the JSK group. A visual inspection revealed once more that the differences noted in the JA and JOK groups were yet again absent in the JSK group for the No-Go trial. A visual comparison between the go and no-go trials (Figure 7.6A and B) shows larger P3 amplitudes at Fz on no-go trials in contrast to go trials and smaller P3 amplitudes at Pz on no-go trials than go trials.
An analysis of the No-Go P3 amplitude showed a main effect for Electrode \[F(2, 18) = 10.55, p < 0.001\] only. A post hoc analysis revealed that the P3 amplitude was largest at the central (Cz: 14.21) and parietal (Pz: 12.51 µV) electrode sites compared to the frontal electrode site (Fz: 5.33 µV). The effect of Condition \[F(1, 9) = 0.94, p = 0.36\] or Correspondence \[F(1, 9) = 0.50, p = 0.50\] did not reach significance. There was no significant interaction between Condition and Electrode \[F(2, 18) = 2.15, p = 0.15\], Condition and Correspondence \[F(1, 9) = 0.49, p = 0.50\], Electrode and Correspondence \[F(2, 18) = 0.33, p = 0.72\] or a 3-way interaction \[F(2, 18) = 2.06, p = 0.16\].

7.4 Discussion

The central finding of this experiment was the observation of the SE in an independent task as shown in the behavioural data. Based on the RDH proposed by Ansorge and Wühr (2004, 2009), we designed an experiment to probe whether the SE could be elicited in a group condition when participants could use spatial features to discriminate alternative responses and represent them as so in WM (JOK task) as opposed to when alternative responses were not represented by spatial codes in WM (JSK task). For that purpose, we took the start-response task developed by Ansorge and Wühr (2004, Experiment 5) and distributed them between a participant and a co-actor. By manipulating the spatial relationship between the trial-start response and the Go response in the group condition, we were able to assess how the codes representing response location may elicit a SE even though participants were assigned a single response and were performing an independent task from the co-actor. In addition to behavioural data, we also recorded electrophysiological data to expand on the work of Sebanz et al. (2006b) by exploring how action planning and control were affected in
a group condition when completing an independent task as opposed to the typical complementary task.

7.4.1 Behavioural Task Performance

According to the RDH, a SE can be elicited for those spatial response features that are used to represent the responses in WM. If this is the case then the SE should be observed when two participants interact on a non-collaborative task if left-right codes discriminate between alternative responses. To show that the SE could be attributed to the spatial discrimination of alternative responses, opposite response keys were assigned to the participant and the co-actor; one to initiate each trial the other to respond to the target (JOK task). Under these conditions, the SE was observed. Interestingly, the SE that manifested itself in the JOK task was noticeably absent when the participant and the co-actor were assigned the same response key to initiate the trial and respond to the target (JSK task). The main difference between these two tasks was that the spatial discrimination of alternative responses was useful in the JOK task but not in the JSK task.

We replicated previous findings showing that in the context of a complementary task, participants were faster to respond on the corresponding trials than the non-corresponding trials (Sebanz et al., 2003a); this was attributed to co-representation. However, we observed a SE when two participants performed in a non-collaborative task when the spatially discriminated responses were required to initiate each trial and to respond to the go targets (JOK task). This suggests that the coding of response position may play a role in giving rise to the SE (however, see Ferraro et al., 2011, which challenges a spatial coding account of the SSE) and that collaborating on a task in an interactive way may not be a necessary condition
for a SE to be elicited when completing a Go/No-Go task. Remember that the role of the co-
actor, in the group condition for both the JOK and JSK groups, was always to initiate the trial
for the participant; they did not interact in a complementary Go/No-Go task with the
participant (e.g., JA task). The design of group condition in the JOK task group allowed us to
demonstrate that by discriminating between functionally alternative responses participants
used spatial codes to represent those responses in WM which gave rise to the SE in a Go/No-
Go task. In contrast, the JSK task which only afforded a single response key in the group
condition would not necessitate it to be spatially represented. As predicted, the SE was absent
in the group condition when a single response key was shared between the participant and the
co-actor. Our findings are in accordance with the findings of Ansorge and Wühr (2004,
Experiment 5), who found the SE when each trial was initiated with a response that was at a
different spatial location to the go response. They also noted the absence of the SE when the
responses could not be discriminated by horizontal spatial codes because there was only a
single response key. The absence of the SE has also been observed when paired participants
each performed two independent detection tasks (Guagnano et al., 2010).

In a recent study by Guagnano and colleagues (2010), paired participants were
instructed to respond to one of two stimulus colours that could appear on the same side of the
response (corresponding trial) or the opposite side of the response (non-corresponding trials).
Participants performed two tasks independently in which both stimuli appeared
simultaneously on 80% of the trials, reasoning that by doing so “eliminated any aspect of
turn taking from the task” (p. 351). They showed that the SE could be elicited in a non-
collaborative task. Guagnano et al. (2010) acknowledged that the nature of their task (non-
collaborative) was considerably different from the task (complementary) used by Sebanz et
al. (2003a) and while they accepted the notion of shared task representations as the mechanism behind the SSE found by Sebanz et al., Guagnano et al. asserted that a different mechanism is behind the SE they found in their experiment. They proposed that sitting alongside another person induced the spatial coding (left, right) of the available responses (see Dolk et al., 2011 for another account of spatial coding and the SSE). In turn when the stimuli were presented along the same left-right dimension as the responses, response conflict arose which resulted from the irrelevant spatial stimulus dimension automatically activating the spatially corresponding response (see Kornblum et al., 1990). We make a similar case to Guagnano et al. (2010) in stating that co-representation cannot account for the SE we observed because shared representations should presumably not be formed in a task that does not require task sharing.

Some may call attention to the possibility that the mechanism responsible for the SE found in the JOK task is different than the mechanism responsible for the SSE found in Sebanz et al.’s (2003a) JA task. We do not disagree with this proposal and acknowledge that the nature of our task is distinct from the complementary Go/No-Go task used in previous task sharing studies. However, what we have shown is that simply engaging in a task alongside another person, whether it is complementary or independent in nature, does not mean that co-representation will occur as has been suggested (at least in a complementary task) (Sebanz et al., 2005a). Based on our behavioural findings, we simply advise others who are investigating co-representation to take a cautionary approach to presuming that co-representation is the driving force behind the observed SE in a joint Go/No-Go task.
7.4.2 Electrophysiological Findings

In efforts to develop a more comprehensive understanding of the underlying processes of co-representation in a complementary task, electrophysiological methods were used. Modulation of the P3 component has been shown when a response is required in one situation (go trial) but must be suppressed in another (no-go trial). Previous ERP studies using the 2-choice Simon task have shown a larger in Go P3 amplitudes at centroparietal sites on spatially corresponding trials compared to non-corresponding trials (Ragot, 1984; Renault et al., 1989; Valle-Inclán, 1996). This difference in amplitude size has been associated with variations in the demands of stimulus related processes (Kok, 2001). Sebanz et al. (2006b) noted two effects: (1) larger Go P3 amplitudes to corresponding in contrast to non-corresponding stimuli across conditions (solo and group), and (2) smaller P3s to non-corresponding stimuli in the solo condition compared to the group condition. They argued that the former finding reflects perceptual interference while the latter reflects response conflict that resulted from co-representation. We failed to replicate these results across the solo and group condition of our JA group. In fact the interaction between condition and correspondence was nowhere near significant \[ p = 0.54 \] and we did not find a main effect for correspondence \[ p = 0.13 \]. Tsai et al. (2008) reported a reverse pattern in which the non-corresponding trials elicited a larger P3 amplitude in their joint action study; however, they were examining how action planning and control were influenced by interacting in a shared task with a biological vs. non-biological agent and attributed their pattern of results to “positional belonging” (p. 2022).

A visual inspection of the grand averages for go trials in the JA group (Figure 7.4A) showed smaller P3 amplitudes on the non-corresponding trials in the group condition than
the solo condition at both Cz and Pz. This finding could be interpreted to mean that there was less conflict when selecting a response for participants in the group condition when processing a stimulus that did not spatially correspond with the required response. How does this reconcile with our behavioural results in which we found a SSE? Perhaps less processing efforts were necessary in the group condition compared to the solo condition which is determined by task load (Kahneman, 1973; Navon & Gopher, 1980). The instructions in the solo condition emphasized to participants to respond as quickly and as accurately as possible to one stimulus colour while ignoring the other. While the task instructions given to participants in the group condition were exactly the same, there was also the emphasis on what the co-actor’s role and task would be. Resource demands may have been allocated differently under these two contexts such that performing with another person reduced subjective control (e.g., Gopher, 1992) which in turn modulated processes in action planning. Thus, performing with a co-actor may have alleviated the processing efforts that would entail the full evaluation of non-corresponding stimuli referring to the other’s response as would be the case in the solo condition. Perhaps the postulated co-representation that is taking place under the group condition in the JA task group is giving rise to the behavioural effect we observed and the nature of the instruction changed what participants regarded as being relative to the task. Knowing that the co-actor was responding to the stimulus that the participant was instructed to ignore may have altered how the stimuli were evaluated with respect to action planning resulting in a smaller positivity on non-corresponding trials in the group condition compared to the solo condition. We found similar Go P3 amplitude patterns in the solo and group conditions for the JOK task group (see Figure 7.5A) when participants performed two independent tasks. Task relevance could also be a determinant of the smaller
Go P3 in the group condition. The same Go/No-Go task was performed in the solo condition by those in the JOK and the JA task groups and the instructions given to them were identical. Those given in the group condition in the JOK task were the same as the solo condition but the experimenter also outlined the co-actor’s task which was to initiate each trial for the participant by pressing the opposite response key. We reasoned that if the alternative responses were being discriminated according to their spatial features in the group condition then the amount of capacity allocated to the non-corresponding stimuli may have been reduced since the co-actor has been assigned to the opposite response which still interacts with the codes representing the stimuli. This would also account for why the SE is still observed in the RT data. In contrast, there was no difference in the Go P3 amplitude between the solo and the group conditions in the JSK task group. The responsibility of the co-actor in the group condition was to start each trial for the participant by pressing the same response key the participant used to respond to their specified stimulus colour. Unlike the task performed in the group condition under both the JA and the JOK task groups, the relevance of the stimuli (corresponding vs. non-corresponding) may have changed the processes involved in the task despite the fact that a co-actor was engaged in the task. The constraints, or lack thereof, of not having to spatially discriminate the single response could account for why the amplitude of the Go P3 was no smaller or larger across the solo and group condition. The task simply did not create a set of circumstances which would allow for the offset of any processing effort as thought to be taking place in the group condition of the JA and JOK task groups. Both the participant and the co-actor were using the one and only response key to carry out their independent part of the task which reduced the complexity of the processes involved in stimulus evaluation keeping the task relatively equivalent to that completed in the
solo condition. Therefore the degree of effort that needed to be invested by those in the JSK task group when performing in the group in order to maintain a particular level of performance from the solo condition did not change.

The No-Go P3 effect is associated with inhibitory activity such as when a response needs to be withheld when a particular stimulus is presented (Eimer, 1993; Jodo & Inoue, 1990; Kopp et al., 1996; Pfefferbaum et al., 1985; Roberts, 1994). According to Sebanz et al. (2006b), participants performing in a complementary task should co-represent and in doing so increased response inhibition would be necessary to refrain from making a response when the stimulus refers to a co-actor’s response. And while a No-Go P3 component would still arise in the solo condition it should still be smaller than that observed in the group condition because co-representation should not occur when performing the Go/No-Go task alone and the need to inhibit a response would be reduced. Despite having shown the behavioural SSE, our analysis showed a trend toward reduced No-Go P3 amplitudes in the group condition compared to the solo conditions. Upon visual inspection of the grand averages for the no-go trials in the JA task group (Figure 7.4B), the P3 amplitude appears to be reduced in the group condition compared to the solo condition; this difference approached significance. This change was taken as an indicator to suggest that response inhibition was easier in the group condition. To explain why it may have been easier for participants to inhibit responses in the group condition, we revisit our account for the smaller Go P3 amplitude in the group condition in both the JA and JOK task. One factor to consider is that the co-actor is assigned their own distinct response key to that of the participant in order to carry out their part of the task. This created a context in which both the participant and the co-actor had their own responsibility in the task irrespective of whether the task was complementary or non-
collaborative in nature. Another factor to bear in mind is the participation of the co-actor in the task may have eased the tendency, or perhaps necessity to anticipate the other’s action and participants ultimately concentrated on their own part of the task. Even though participants could observe the co-actor’s actions, this was not enough for them to increase their need to withhold a response. How participants approached the task may have been influenced by the emphasis they placed on the instructions regarding the role of the co-actor in the group condition.

We anticipated that the No-Go P3 amplitude for the JOK task group would be larger in the group condition than the solo condition because there would be an increased need for action control when presented with a stimulus that refers to the co-actor’s response. This need for increased response inhibition would stem from the spatial features used to form the response representation in WM that consequently interact with the spatial stimulus codes. Surprisingly, we showed that the No-Go P3 amplitude was reduced in the group condition (see Figure 7.5B) which was what was also found in the JA task group. This was in spite of the fact that our behavioural results were in line with the predictions made by the RDH, in which the SE was absent in the solo condition but reappeared in the group condition. We refer again to the notion that when performing the Go/No-Go task under the group condition, the task relevance of the non-corresponding stimuli was reduced. The need to inhibit one’s response may have necessitated less processing as reflected in the smaller No-Go P3 amplitude detected under these conditions. The No-Go P3 amplitudes were no different across both the solo and group condition in the JSK task group. Taking a look at Figure 7.6B, we can see that as we move from the frontal to the posterior site, the No-Go P3 component representing the solo and group condition are not readily distinguishable from each other.
unlike those in the JA and JOK task groups which are noticeably separable at the central and posterior sites (see Figures 7.5B and 7.6B). Comparable levels of inhibitory control on no-go trials for the JSK task group across the solo and group conditions suggests that there may be something unique about the inhibitory processes involved in the JA and the JOK groups. The key feature that distinguishes the JSK group from the other two is that there is no alternative response in the group condition that is either assigned to the co-actor (JA group) or that is spatially discriminated based on the context of the task (JOK group).

The question we find ourselves coming back to is, why would the need to inhibit one’s tendency to act be reduced when performing the Go/No-Go task with a co-actor than when performing the task alone in both the JA and JOK tasks? We feel that the meaning of the “to be ignored” stimuli changed under varying social contexts. For the JA group, when performing a shared task perhaps inhibitory control was dampened because one knew that there was someone else responsible for responding to stimuli that was task-irrelevant (i.e., non-corresponding stimuli). This knowledge may have attenuated the inhibitory processes in the group condition leading to reduced No-Go P3 amplitudes. Whereas performing alone required participants to be fully engaged in the task as there was no co-actor taking care of the other stimulus. For the JOK group, we reason that the co-actor’s role in initiating each trial for the participant using the opposite response key eased the task demands such that less inhibitory control is required compared to the solo condition. This explanation for the present ERP data still fits with the SSE that we observed in our behavioural data as we are not making the case that co-representation is not taking place. What we are putting forth is an alternative interpretation for our failure to replicate the No-Go P3 finding shown in previous studies (Sebanz et al., 2006b; Tsai et al., 2008).
On a final note, our behavioural results showed a significant SSE in the JA task group and a significant SE in the JOK task group when performing in the group condition; there was no SE in the solo condition of either task group. An important issue to address is how these findings reconcile with our ERP findings. Firstly, why would we see reduced No-Go P3 amplitudes in the group conditions compared to the solo conditions in both the JA and JOK task groups implying that there was reduced response inhibition in the group condition? In contrast to Sebanz et al. (2006a or b), this reduced inhibition in the group condition was not observed nor would it be associated with a joint action effect. We would argue that in the group condition, participants may have placed less weighting on the task instructions such that they focused on responding to the one stimulus feature (i.e., red ring) and relied on the co-actor to respond to the other stimulus feature (i.e., green ring) which they were to ignore. As a consequence, when the to-be-ignored stimulus was presented, participants had less difficulty withholding their response than those in the solo condition because there was no co-actor to take on the load of responding to the to-be-ignored stimulus feature. No SE was observed in the solo condition in either the JA or the JOK task groups because there was no co-actor to either co-represent or alternative responses to spatially discriminate. However, in the solo condition, the context of the task changes because now there was no co-actor who could now be co-represented or an alternative response that can be discriminated.

Despite having replicated Sebanz et al.’s (2003a, 2005a) behavioural findings (i.e., SSE), the fact that we also observed a SE when two participants performed two independent tasks (i.e., JOK task) suggests that an alternative interpretation of the SSE is warranted. According to Sebanz et al. (2003a), the SSE arises because participants form a shared representation of the task which creates response conflict on non-corresponding trials.
However, this explanation cannot account for our findings. Our experiment demonstrated that when two participants are performing independent tasks, the SE can be elicited when spatial codes potentially discriminate between the alternative responses (e.g., JOK task) but not when there is only a single response (JSK task).
7.5 Bridging Summary

Study 5 showed a strong joint Simon effect (JSE) when social pointing stimuli were used in a joint action task. We continued using these social cueing stimuli in Study 6 in which we investigated whether the JSE can be observed when paired participants performed two independent tasks alongside each other. We observed the joint SE when participants were assigned opposite response keys but not when they were assigned same response key to initiate the trial and perform the Go/No-Go task. This suggests when left-right codes discriminate between alternative responses, as in the case that each participant was assigned separate response keys, then the SE can arise. When a single response was assigned to both participants, there was no reason for spatial coding to discriminate that particular response as it was not useful to the task; hence no SE. Our ERP data did not corroborate previous work showing increased inhibition when engaged in a group Go/No-Go task as opposed to a solo Go/No-Go task which was interpreted as evidence for co-representation (Sebanz et al., 2006b). In fact, we showed that there was a decrease in action suppression in the group condition compared to the solo condition. We also observed a similar pattern of ERP results when participants performed two independent tasks and assigned alternative responses. In contrast, when participants performed two independent tasks using the same response key, there was no apparent difference between the solo and group conditions. To reconcile our behavioural and electrophysiological results, we proposed that the significance of the “to be ignored” stimuli altered under varying social contexts. We put forth that perhaps inhibitory control dampened in the group condition because another person was now responsible for responding to the task-irrelevant stimuli. This is in contrast to the solo condition in which
participants may have been more engaged in the task because there was no co-actor who was responsible for the “to be ignored” stimuli which required more inhibition on their part.

Finally, we conclude our investigation in joint action with Study 7 which explored the notion of task co-representation using a different experimental paradigm. Using a modified version of the response precuing task (see Miller, 1982), we examined performance when participants had two alternative responses at their disposal in the joint condition as well as advance information about the required response. The 4-choice task was performed alone in its entirety, divided between two participants or performed alone using only one response hand (making it a 2-choice task). The purpose of the following study was to investigate and explore the influence that the number of S-R alternatives (i.e., set size) and advance information (i.e., precue) about the required response has on co-representation.
8 Chapter: Study 7 - Joint Action Effects in a Social Response-Precuing Task

8.1 Introduction

Engaging in joint action may not be as simple as it looks. Consider two ballroom dancers who appear to effortlessly coordinate their movements across the floor, as if moving as a single entity. Yet, here we have these two separate bodies, these two unconnected minds that are somehow able to tune in to each other in such a way that they interact flawlessly. What is quickly realized is that the mechanisms underlying complex joint action are far from trivial. The mechanisms through which joint action is thought to be achieved are joint attention, action observation, action coordination, and task sharing (Sebanz et al., 2006a). Task sharing, specifically, has become a popular means of examining social interaction.

Knowledge of what another person is doing when task sharing can provide us with an effective means of predicting what they will do next. What has been proposed in the task sharing literature is that individuals not only form a representation of their own task but also that of the co-actor even when it may not be necessary to accomplish the goal of the task. The first line of evidence in support of co-representation was offered by a series of behavioural experiments (Sebanz et al., 2003a) that used a variant of the Simon task (Simon & Rudell, 1967). In the classical Simon task, responses are based on a non-spatial feature of the stimulus (e.g., shape or colour) and its location is irrelevant to the task. The general findings are that responses are significantly faster and less prone to error when stimulus location and response position correspond (i.e., left stimulus-left response) than when they do not (i.e., left stimulus-right response). At the present time, the term Simon effect (SE) refers
to these correspondence effects (De Jong et al., 1994; Lu & Proctor, 1995; Simon & Rudell, 1967). An important observation about the SE is its typical absence when participants perform a Go/No-Go task in which participants are asked to respond to one of the stimulus colours with a pre-defined response while ignoring the other stimulus colour (cf. Ansorge & Wühr, 2004; Hommel, 1996). This pattern of findings (the SE in the 2-choice task but not the Go/No-Go task) allowed Sebanz et al. (2003a) to design the first social Simon task to test for co-representation.

When two participants shared the Simon task, performance was comparable to when participants completed the task on their own (Sebanz et al., 2003a). To create a “social” condition, they distributed the 2-choice Simon task between two participants such that each responded to one of two target stimuli making a single key press response. Participants also performed a solo Go/No-Go Simon task. The only difference between the solo and the group condition was that in the former case, participants performed the Go/No-Go task alone whereas in the latter case, participants performed a complementary Go/No-Go task alongside a co-actor. In the group condition, participants were presented with pictures of a hand pointing to the left, right or straight ahead and they were instructed to respond to the colour of the ring on the index finger (red or green). In the solo condition, participants were presented with the same stimuli; however, they performed the Go/No-Go task alone. Sebanz et al. (2003a) replicated the standard SE when participants performed the 2-choice Simon task. The SE was notably absent in the Go/No-Go task in the solo condition. In the group condition, the SE re-appeared with responses being significantly faster when the direction that the hand was pointing corresponded with the required response (e.g., finger pointing right-right response); this has been described as the social Simon effect (SSE). Sebanz et al.
contend that the SSE arises in the group condition because co-representation occurred which meant that the co-actor’s task had been integrated in the participant’s own action plan. This resulted in interference effects that were not observed when participants performed the same task in the solo condition. Studies have since replicated these findings using similar variants of the Simon tasks (Tsai et al., 2006; Welsh, 2009) and have shown that co-representation can be influenced by factors such as interactor relationship (Hommel et al., 2009), interacting with a biological vs. non-biological agents (Tsai & Brass, 2007), engaging in a cooperative vs. competitive context (deBruijn et al., 2008; Ruys & Aarts, 2010; Study 2; see Iani et al., 2012 for a contradictory result), and the absence or presence of a co-actor (Tsai et al., 2008, Vlainic et al., 2010; see Welsh et al., 2007 for a contradictory result).

The general aim of this study is to further explore the boundary conditions of co-representation and the prediction it makes in task sharing. More specifically, we sought evidence in support of (or against) the co-representation account using a different experimental paradigm: a modified version of the spatial response-precuing task developed by Miller (1982). A number of studies have used a variant of the binary choice Simon task to demonstrate that participants co-represent a co-actor’s stimulus-response (S-R) mapping in their own action plan. However, the influence that the number of S-R alternatives (i.e., set size) has on whether co-representation will occur has yet to be examined, at least to our knowledge. When a task imposes a heavy cognitive load it may require more processing effort which may be limited to begin with. Any spare resources may not be sufficient to activate the processes that lead to response co-representation and is therefore forfeited in
favour of achieving the task goal\textsuperscript{23}. We also wanted to investigate whether participants form
shared representations of the co-actor’s responses even if they are given advance information
about the required response by way of a precue.

events in the environment and others’ actions allow one to prepare actions in response to
events that will only occur a considerable time ahead” (p. 73, italics added). Preparation is a
characteristic feature that humans exemplify and the precue paradigm has been utilized to
investigate preparation processes involved in perception and action. To do so, participants are
presented with varying amounts of advance information (i.e., full, partial, or no information)
about the upcoming response. By reducing the uncertainty of the upcoming response, it is
thought that performance will improve because only information at the cued location(s)
needs to be inspected (see Luck et al., 1996 for details about the uncertainty reduction
model). Just as one can prepare a response by knowing what a co-actor will do (co-
representation), one can also prepare a response(s) when a precue is presented. We in turn
asked whether co-representation would occur when performing in a shared response-precuing
task. Two different tasks were completed: (1) a group response-precuing task in which four-
choices were distributed between the participant and the co-actor\textsuperscript{24} and, (2) a solo response-
precuing task in which one participant alone performed the exact same task as in the group
condition. To provide a clearer understanding of our hypotheses, a brief introduction to the
response precuing paradigm follows.

\textsuperscript{23} We will use the term ‘cognitive load’ to refer to the total amount of information imposed on working memory
at any given time.
\textsuperscript{24} One participant was assigned to respond to one of two targets that appeared to one side of fixation while the
other participant responded to one of two targets on the other side of fixation.
8.1.1 The Response Precuing Paradigm

In the response precuing paradigm participants are instructed to prepare a response based on advance information provided by a precue. A well-known application of this technique is in Rosenbaum’s (1980) work in which he examined the nature of movement preparation. Using a variant of the choice RT task, participants were instructed to make movements that varied along more than one parameter (e.g., arm, direction, extent). Prior to the onset of the imperative stimulus, a precue was presented and offered varying amounts of information (e.g., none, partial, full) about the response parameters. The general finding was that when the precue conveyed information about some or all of the movement parameters, response times (RTs) were shorter compared to when the precue conveyed no information about the movement parameters. This observation has been described as the response precuing effect. It was assumed that the information provided by a precue allows the motor system to partially prepare the necessary response (Rosenbaum, 1980) and that the effect specifically impacts the motoric stage (see De Jong et al., 1988; Leuthold et al., 1996). Others have challenged this claim, making the case that the effect facilitates response selection (see Goodman & Kelso, 1980). For example, Goodman and Kelso (1980) pointed out that as the amount of information about the impending response increases, the number of S-R alternatives decreases (i.e., none: 4-choice → partial: 2-choice → full: simple). According to Hick’s law, choice RT is linearly related to the bits of information that need to be processed in order to select a response such that RT increases as the bits of information increases (see Hick, 1952 and Hyman, 1953). The debate surrounding the question of whether response precuing effects originate in the premotoric or motoric portion of RT is still
questioned; however, Miller’s (1982) work did present additional evidence that precues affect the motoric processes.

Miller (1982) modified Rosenbaum’s (1980, 1983) movement precuing task, devising what was aptly called the (four-choice) spatial response-precuing task to examine the preparation of discrete finger responses. The general intent of his study was to examine the nature of information transmission from stimulus identification to response programming but his specific interest was whether response preparation could start before the stimulus identification process was complete. Participants were instructed to align the index and middle fingers of their left and right hands with horizontally defined stimuli. The stimulus was a plus sign (+) and the sequence of events for each trial was as follows: (1) the warning signal (a row of four plus signs) which indicated the four possible S-R locations, (2) the precue (a row of two or four plus signs) presented below the warning signal which indicated the possible stimulus target position, (3) the stimulus target (a single plus sign) which indicated the location of the required response. Upon target presentation, the spatially corresponding response had to be made by making the appropriate key press. Four precuing types were used in Miller’s (1982) study. Each of these types differed with respect to the responses (stimulus targets) indicated by the precue. In the hand precue type, the two fingers on either the left or the right hands were prompted. In the finger precue type, the index or the middle fingers on different hands were prompted. In the neither precue type, different fingers on different hands were prompted. In the unprepared precue type, both fingers and both hands were prompted. While the unprepared precue type maintains the four-choice RT task precluding any early response preparation, each of the prepared precue types (hand, neither, finger) reduced the former four-choice RT task to a 2-choice RT task, allowing some
selective preparation to take place. Miller’s findings were that responses prepared on the same hand were more advantageous than responses prepared for the same finger on different hands. Miller proposed that this reflected a well-organized motor system since responses programmed for one hand would be managed by one hemisphere whereas responses programmed for two different hands would be organized by both hemispheres. Since then, a number of electrophysiological studies have shown that the beneficial effects of the precuing of hand lies in the motoric stages as opposed to the premotoric stages as once suggested (e.g., De Jong et al., 1988; Leuthold et al., 1996; Requin et al., 1993).

8.1.2 The Social Response-Precuing Effect: Rationale and Hypotheses

The purpose of this study was to examine whether individuals co-represent even when response-relevant information is provided to them by way of a precue. The rationale behind our investigation was that when engaging in a complementary task, co-representation makes it possible for participants to anticipate a co-actor’s future actions and to prepare a response to these actions (Sebanz et al., 2006a). In the response-precuing paradigm, information is offered about the impending response which allows the participant to selectively prepare components of the response before the onset of the target stimulus. The commonality between these two tasks is that they both afford the participant a certain degree of advance preparation. The question we raised was whether co-representation occurs in a task that provides participants with advance information about the upcoming response.

To address this issue, we distributed Miller’s (1982) 4-choice spatial response-precuing task between paired participants. By doing so, we transformed the former 4-choice RT task into two 2-choice RT tasks shared between two participants. As mentioned earlier,
what makes this task unique to others examining joint action is that participants are making binary responses as opposed to a single response; it is still, however, a Go/No-Go task as participants would have to refrain from responding to the co-actor’s stimuli. There were two conditions under which the task was performed: (1) a group condition in which the four choices of the task were distributed between the participant and the co-actor and (2) a solo condition in which one participant alone performed the exact same task as in the group condition. In the group condition, we questioned whether participants would form shared representations of the co-actor’s task despite having access to information about the upcoming response. It should be pointed out that we introduced a fifth precue type, *full*, which would identify one response alternative. The predicted pattern of differential precue benefits for RT would be *full* < *hand, neither, finger* < *unprepared* in the group condition if co-presentation occurred; we will describe this as the social precuing effect (SPE) ²⁵. In other words, the overall pattern of performance across precue conditions should be similar to completing the whole task alone²⁶, the only difference possibly being overall faster RTs in the group condition in contrast to the solo condition, attributed to a phenomenon known as social facilitation (e.g., Aiellop & Douthitt, 2001; Zajonc, 1965). Our prediction was based on the notion that in the group condition, even though participants were each only responsible for two of the four possible responses, they would co-represent the co-actor’s responses. According to Sebanz et al. (2006a), this co-representation happens ‘quasi-automatically’ even when it offers no advantage to one’s own task performance. Should the precue highlight response positions that prompt both the participant and the co-actor then

---

²⁵ The pattern of differential precueing benefits has often showed the ‘hand advantage’ for shorter preparation intervals (i.e., shorter than 1500 ms) but as the preparation interval increases (i.e., 3000 ms) RTs are comparable across the *hand, neither* and *finger* precue types (see Reeve & Proctor, 1984). When we refer to the standard pattern of differential precue benefits, we are referring to the findings at longer preparation intervals.

²⁶ Null findings will be interpreted as evidence for co-representation.
what might be a simple RT trial for the participant becomes a 2-choice RT trial if a response representation has been formed. Consider, for example, a trial on which a finger precue is presented, indicating that the upcoming response will require an index finger response on the part of either the participant or the co-actor. Participants prepare responses for both index fingers even though they are only responding with their own index finger. Consequently RTs would be longer for this precue type than the full precue type which prepares a single response from the participant or the co-actor. What should be treated as a simple RT trial is treated as a 2-choice RT trial because the precue has triggered a representation of the other’s response. Despite the fact that the participant is only responsible for making a single response in each of the preceding conditions, RTs will differ if a shared task representation has been generated. The pattern of differential precue benefits in the group condition should be similar to that of someone performing the entire 4-choice RT task on their own if co-representation has occurred. In the case that shared representations were not created then the pattern of differential precue benefits should reflect the transformation of 4-choice RT trials to 2-choice RT trials and 2-choice RT trials to simple RT trials. For example, trials that cue all four response positions will prompt two relevant response positions for the participant and the co-actor in the group condition. Both the neither and the finger precues prompt two possible response positions but only one of those response positions is relevant for response preparation for the participant and the co-actor. Assuming that participants are mapping their responses onto target stimuli in a one-to-one fashion, only information pertaining to their assigned response positions should be processed and any response irrelevant information should be disregarded. We expect RTs for the neither and the finger precue trials to be similar to those for the full precue trials as these precue types would offer pertinent
information about a single response position to the participant. The hand and the full precue types should elicit similar effects to what is observed in differential precue benefits (i.e., \(\text{full} < \text{hand} \text{ RT}\)). Taking all precue types into account, the predicted pattern of differential precue benefits should be \(\text{full} < \text{finger, neither} < \text{hand} < \text{unprepared}\) in the group condition assuming co-representation has not taken place.

The rationale behind our solo condition, in which participants performed the same task as they did in the group condition, was the recognition that a control condition was needed to make comparisons with the results of the group condition. In the group condition, we took Miller’s (1982) modified 4-choice response-precuing task and distributed it between a participant and a co-actor such that they engaged in task sharing. Both the participant and the co-actor were assigned either the two rightmost response positions or the two leftmost response positions. Under the solo condition, participants performed the same task as they did in the group condition by themselves such that they were responsible for responding to targets that appeared in one of the two response positions on the far right or the far left depending on their group S-R mapping. This task design ensured that we could come to some resolve about any differences we may observe between the solo and group conditions which cannot be attributed to any pre-existing differences when performing one half of the task alone. In other words, if the results of the group condition supported the claim that the other’s responses were represented then we need to have knowledge about the pattern of results under a set of solo conditions to make such inferences. Having participants perform the same group task in a solo setting is comparable to the inclusion of the individual Go/No-Go Simon task by Sebanz et al. (2003a).
8.2 Experiment 7A: Group Condition

8.2.1 Methods

8.2.1.1 Participants

Twenty healthy undergraduate students (14 females; mean age = 24.3 years, SD = 4.4) with no history of neurological problems and normal or corrected-to-normal vision volunteered for this experiment. The participants were all right-handed by self-report and were naïve with regard to the purpose of this experiment. The experiment was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent.

8.2.1.2 Apparatus

A custom-built response box (22 cm X 15 cm) containing four push buttons (1.2 cm in diameter) was placed in the centre of a table (152 cm X 76 cm). A wooden box (40 cm X 14 cm) was placed over top of the response box to provide a surface on which to place the computer monitor and to remove visual feedback of the responses made by one’s co-actor. The flat screen computer monitor (Dell 2408WFP 19") was positioned in the centre of the wooden box (display facing up, parallel with the surface of the table) in such a way that the stimuli presented on the display matched up spatially with the push buttons on the response box.

We originally conducted two separate experiments. In our first experiment, participants performed the response-precuing task with a co-actor (group condition) and then performed the entire task using all four response keys all alone (solo condition). This was subsequently followed by a second experiment in which we ran the same task under the solo condition from the first experiment but we also ran another task under the guise of a solo condition in which the participant performed only one half of the response-precuing task. Note that the data reported in this chapter for the solo and the group conditions are drawn from two different samples of participants. We have included a separate appendix that reports the results for the response-precuing task when participants performed the entire task alone.
box underneath (i.e., in a left-to-right order). The participants and the co-actor were randomly assigned to one of two chairs positioned across from each other on each side of the table (see Figure 8.1 for experimental setup). E-Prime™ version 2.0 was used to randomly display the precues and target stimuli and to record response latencies and errors.

![Figure 8.1 Experimental setup. Gray shaded area indicates parts of the display obscured from participants’ view.](image)

### 8.2.1.3 Stimuli

The stimulus display for each trial consisted of a warning signal, a precue and a target stimulus with the entire display centred on the computer display. As shown in Figure 8.2, the warning signal was a gray fixation cross (0.4 cm × 0.4 cm) at the centre of the display with

---

28 The decision to position participants across from each other rather than side-by-side was to deal with the issue of performance space since the stimulus display was approximately 4 cm and the response keys were spatially aligned with them.
two gray rectangular placeholders (1.3 cm X 0.6 cm) flanking each side of it on a black background for 750 ms. The distance between the fixation cross and the placeholders was 0.4 cm. The onset of the precue onset immediately followed the warning signal. It consisted of the same fixation cross and placeholders, however, one of four, two or four, or all four placeholders were highlighted in yellow to indicate the upcoming response position(s). This remained on display for 1500 ms. The target was a red star (0.4 cm X 0.4 cm) which appeared in one of the highlighted placeholders immediately after the precue presentation. The target disappeared after a response was made; if no response was detected, the target disappeared after 1000 ms.
Figure 8.2  Stimulus sequence in each trial. Trials started with the presentation of a warning stimulus. After 750 ms, the precue stimulus appeared for 1500 ms then the target appeared in one of four placeholder positions for 1000 ms or until a response was detected. The inter-trial-interval (ITI) was 1000 ms.

The four precuing types from Miller’s Experiment (1982) were used in this study but differed in terms of the stimulus properties (i.e., their warning signal, precue and target consisted of plus signs). We introduced a fifth precuing type in which indicated the exact position the target would appear. Figure 8.3 illustrates an example of each type of precue when the impending response required an index finger response on the right hand. For the unprepared precue type, all four placeholders were highlighted and the target appeared in any of those four positions. For the prepared precue types, only two of the four placeholders were highlighted and the target appeared in one of the two positions indicated by the precue.
In the *hand* precue types, the two placeholders assigned to either the left hand or the right hand were highlighted. In the *finger* precue type, the two placeholders assigned to the index fingers or the middle fingers were highlighted. In the *neither* precue type, the two placeholders assigned to the index finger of one hand (left) and to the middle finger of the other hand (right) were highlighted. Finally, in the *full* precue type, only one of the four placeholders was highlighted indicating the exact position the target would appear.
Figure 8.3  Example of stimulus displays for each precuing type when the target indicated a right index finger response. Fixation and placeholders are black instead of gray for the ease of viewing.
At the start of the testing session, participants completed 20 practice trials to familiarize themselves with the task and the response apparatus. After the practice session, participants completed five blocks of 92 trials for a total of 460 trials. Of this total number of trials, 80 were for the unprepared precue type, 80 were hand precue type and 300 were finger, neither, full precue types; the order of these trials was random.

8.2.1.4 Procedures

Participants were scheduled for testing in pairs and were introduced upon arrival. They were then each randomly assigned to one of two seats. The seats were arranged in such a way that participants faced each other from across the table. The experimenter identified which response hand each participant would be using and instructed them to place their index and middle finger on two of the four permissible response keys; their inactive hand was placed on their lap. Participants were assigned to one of two response positions: (1) index and middle fingers placed on the two left-most keys of the response box or (2) index and middle fingers placed on the two right-most keys of the response box. After set up, participants were given verbal instruction regarding the nature of the task. They were told that each trial would consist of a warning stimulus, followed by a precuing stimulus, and finally a target stimulus (see Figure 8.3 for stimulus sequence in each trial). The stimulus display was described in detail and participants were instructed to maintain eye gaze on the fixation cross at the centre of the screen throughout the trial. The experimenter ensured that participants were aware of the other’s S-R mapping and that the precue may prepare one of them to respond or both of them to respond. Participants were explicitly told to use the precue information to prepare
their responses as it was valid 100% of the time; the five different precue types were described in full detail to them.

8.2.1.5 Results

RT was defined as the time from the onset of the target stimulus until a key press response was detected. An error was considered to be the failure to make a response or if the wrong key was pressed; these trials were eliminated from the data set. Mean RTs and proportion of errors were calculated for each participant as a function of precue type. If the RT on any trial fell two standard deviations above or below the mean RT for a particular precue type then it was eliminated from further analysis. When analyzing the data, only the RTs derived from the index finger of the hand used to perform in the solo condition was included in the calculation of the means.
Figure 8.4  Mean RT for each precue type in the group condition. The SEM for unprepared, hand, neither, finger and full precue types were 18 ms, 17 ms, 19 ms, 16 ms and 17 ms, respectively.

See Figure 8.4 for the mean RTs across the five precue types. A one-way repeated measures analysis of variance (ANOVA) on these data of the five Precue types (unprepared, hand, neither, finger, full) yielded a significant effect [$F(4, 76) = 10.95, p < 0.01$]. Tukey’s honestly significant difference (HSD) test was used to conduct post hoc analyses and indicated that RTs for the unprepared precue type (397 ms) were no different than the hand precue type (391 ms) but that responses were slower for these two precue types compared to the other three precue types (346 ms, 340 ms, 312 ms for neither, finger, full, respectively). These results do not reflect the standard pattern of differential precue benefits. Experimental studies have shown that a modification in the amount of information provided by a precue can increase or decrease performance levels (Goodman & Kelso, 1980; Miller, 1982; Reeves
Typically, RTs for the unprepared precue type should be longer than the other four precue types; however, this was not the case. Despite the fact that the hand precue type reduced the set size from four to two, RT was no different to that of the unprepared precue type. Typically, the standard pattern of differential precue benefits shows faster RTs to targets that are preceded by a hand precue type compared to an unprepared precue type. However, this task was performed under the group condition which means that it was distributed amongst two participants; these results will be discussed later in the context of co-representation. The post hoc analysis also showed that RTs in the full precue type (312 ms) were faster than unprepared and hand (397 ms and 391 ms) precue types but no different from neither or finger (346 ms and 340 ms, respectively) precue types. This finding also failed to follow the notion that providing full advance information about the upcoming response would be more beneficial than providing partial advance information, as in the case of neither and finger. Once more, these results will be discussed in greater detail in the Discussion section when a comparison can be made with our results from the solo condition.

8.3 Experiment 7B: Solo Condition (2-Choice Task)

The results from Experiment 7A alone cannot offer support for the SPE or that shared representations are formed in a modified response-precuing task; a comparison condition is necessary. In the typical response-precuing task, participants perform the task on their own and respond to targets that appear in any of the four response positions. The task we required was one in which participants were only responding to targets that appeared in two of the four designated response positions, as they did when performing the task in the group
condition. While it is known that performing a Go/No-Go Simon task is an exception to the
standard finding of a SE (cf. Ansorge & Wühr, 2004; Hommel, 1996), how the precuing
effect is impacted when responding to targets when they appear in two of the four designated
response positions is undetermined. Thus, Experiment 7B was designed to follow the logic of
previous experiments in which group performance was compared to solo performance when
completing the exact same task. This would allow us to examine how precues conveying
information about responses for ignored response positions are processed. We predicted one
of two outcomes: (1) when complete information is given about one’s assigned responses
(full, finger, neither), RT will be shortest, followed by no information (unprepared, hand), or
(2) when all information is given about one’s assigned responses (full), RTs will be shortest,
followed by partial precues (hand, neither, finger) and then no beneficial information
provided by the precue type (unprepared). Should performance follow the first prediction
then this would suggest that participants used only advance information pertaining to the
responses to which they were assigned. Should performance follow the second prediction
then this would suggest that participants processed all the information provided to them by
the precue even if they pertained to responses for which they were not responsible. An
alternative explanation is that even though participants are basing their response on their two
assigned response positions, there is still a level of discrimination that takes place if either of
the two unassigned response positions is cued. That is to say, if one of two assigned response
positions is cued as well as an unassigned response position (e.g., neither or finger precue
type) then some degree of processing will be necessary to either inhibit or initiate a response
upon target presentation; this will result in longer RTs.
8.3.1 Methods

8.3.1.1 Participants

Eight healthy undergraduate students (5 females; mean age = 21.9 years, SD = 3.4) with no history of neurological problems and normal or corrected-to-normal vision volunteered for this experiment. The participants were all right-handed by self-report and were naïve with regard to the hypothesis of the experiment. The experiment was conducted in accordance with the ethical guidelines set out by the University of British Columbia and all participants gave written consent.

8.3.1.2 Apparatus

The apparatus was the same as in Experiment 7A.

8.3.1.3 Stimuli

The stimuli were the same as in Experiment 7A.

8.3.1.4 Procedures

The task was the same as in the group condition. The only difference was that participants performed the task alone and they were instructed that responses were not required for those targets that appeared in the two ‘to be ignored’ response positions.
8.3.1.5 Results

The same criteria described in Experiment 7A was used for the analysis of the data in Experiment 7B.

Figure 8.5 Mean RT for each precue type in the solo condition (2-choice). The SEM for unprepared, hand, neither, finger and full precue types were 38 ms, 34 ms, 37 ms, 39 ms and 35 ms, respectively

See Figure 8.5 for the overall mean RT of each precue type for the solo condition. A one-way repeated measures ANOVA was run on the RT of the five Precue types (unprepared, hand, neither, finger, full) and a significant effect was found [$F(4, 28) = 11.01$, $p < 0.01$]. Post hoc analyses, using Tukey’s HSD ($p < 0.05$), showed that when no advance information was given by the precue (unprepared) RTs were not significantly different than the hand precue type but that responses were slower for these two precue types compared to
the other three precue types (neither, finger, full). The full precue type had faster responses than all other precue types with exception of neither in which RTs were not significantly different. Now we consider the precue types that provided partial information about the target position. The hand precue type did not differ reliably to all other precue types apart from being slower than the full precue type. The neither precue type had faster RTs than the unprepared precue type but was comparable to the other three precue types. Finally, the finger precue type yielded faster RTs than the unprepared precue type and slower RTs than the full precue type; it did not differ reliably from the other two partial precue types (neither, hand). These results will be clarified with respect to whether they provide evidence for co-representation and how they compare with the results from the group condition in the Discussion section.

8.4 Discussion

A number of different paradigms have been used to identify the boundary conditions of co-representation in joint action. Early studies transformed the Simon task into one which paired participants could share to determine if they acted independently of each other or if they formed a shared represented of each other’s task rules (Sebanz et al, 2003a, 2005a; Tsai et al., 2006; Welsh et al., 2007). To do so, the two parts of the Simon task was distributed between the two participants, each being asked to respond to one of the two imperative stimuli. Since then, other experimental tasks have been modified to study task sharing such as the SNARC paradigm (Atmaca et al., 2008), the Eriksen flanker paradigm (Atmaca et al., 2011), the end-state comfort paradigm (Gonzalez et al., 2011; Herbort et al., 2012; Ray & Welsh, 2011) and even a musical paradigm (Novembre et al., 2012). The bulk of these shared
tasks have two commonalities: (1) they tend to be a binary choice task divided into a two single response Go/No-Go task, and (2) responses are made as soon as the imperative stimulus appears. This study had two objectives. The first was to conduct an experiment in which participants performed binary choice responses rather than single responses to establish whether shared representations are formed under such conditions (see Wenke et al., 2011). The second was to explore whether co-representation also occurred in a response-precuing task where precue information limits the possible stimulus-response alternatives and lets some advance preparation to take place. We found that a co-representation account is not consistent with the results of our experiments.

In Experiment 7A, participants completed a social version of the response-precuing task (see Figure 8.1) to establish whether they co-represented a co-actor’s task even when advance information about a forthcoming response was provided by a precue prior to the response signal. In the individual response-precuing task, participants make use of this advance information such that RTs are shortest for the full precue type and longest for the unprepared precue type with RTs for the hand, neither, and finger precue types falling somewhere in between (see Appendix A). If this pattern of differential cuing benefits were observed in the group condition then this would provide evidence for co-representation since performance would be similar to executing the task alone. Taking a look at the overall pattern of RTs, we found that the RTs for the unprepared and hand precue types were not statistically different. The RT for the hand precue type was slower than the neither, finger and full precue types. While there was an advantage for the full precue type over the unprepared and hand precue types, this was not the case for the neither and the finger precue types. How do these findings reconcile with the standard response-cuing effect? More
importantly, what is the pattern of precuing effects when participants performed the same half of the task on their own?

**Figure 8.6** Illustration of how set size is reduced for each precue type in a response-precuing task under the solo and group conditions. For example, participant A is instructed to respond to targets that appear in the two leftmost response positions (circled). For the *unprepared* precue type, all four response positions are highlighted but participant A is only responding to two of those four response positions thus reducing task-relevant information.

In Experiment 7B, we examined performance in a solo version of the response-precuing task (see Figure 8.6) carried out in Experiment 7A and the results showed no consistent pattern of differential precuing benefits. Response latencies did not differ between the *unprepared* and the *hand* precue types but both were significantly slower than the
neither, finger and full precue types. The participants’ RTs for the hand, neither, and finger precue types were comparable. Strangely, responses for the full precue type were faster than all precue types except the neither precue type. When the entire response-precuing task is performed alone, the RTs for the unprepared precue type should be the longest and the full precue type should be shortest compared to the other three precue types which should fall somewhere in the middle of the two. In the solo condition, it seems that participants treated the unprepared and hand precue types as having equal set sizes even though all four response positions were highlighted in the former precue type. This inference was based on the fact that RTs for these two precue types did not differ reliably from each other. In contrast, the idea that there is some kind of strategy in which only those precue positions that specify task-relevant responses are processed is unfounded since reducing the set size from two (hand) to one (neither, finger) offered no RT benefit. This would instead support the notion that performance is influenced by precues that indicate that the possible response is in a task-irrelevant position. What we would have anticipated is that RTs for the hand precue types to be longer than the neither and finger precue types. However, if we take a closer look at the data, we note the trend of the RTs with the difference between hand (393 ms) and finger (377 ms) being 16 ms and between hand and neither (363 ms) being 30 ms. Again, in the hand precue type, participants need to prepare both an index and middle finger response on one hand whereas for the finger and neither precue types they only need to potentially prepare one of two fingers which may explain the pattern of RTs just described. Finally, when the precue gave complete information (full) about the response position it produced a benefit over all other precue types except when the index and middle finger were cued (neither). The set size for both the neither and finger precue types was reduced from two to one in the solo
condition and while there was no reliable difference between the *full* and *neither* precue types, this was not evident for the *finger* precue type. This would suggest that when the same finger was cued, participants prepared both responses. Although inconsistent, the pattern of differential precuing benefits in the solo condition does provide us with a set of results to compare with the group condition. 

Before making any attempt to interpret the results of the group condition, we must first identify the precue types in which co-representation could reveal itself. When the precue indicated that the forthcoming target could appear in any of the four response positions (*unprepared*), both participants would need to prepare their respective response; this would also be the case for the *neither* and *finger* precue types. Each of these precue types necessitated the preparation of a response on the part of each participant (see Figure 8.6). In contrast, the information relayed by both the *hand* and the *full precue* types is only relevant to one of the two participants (see Figure 8.6). Should the patterns of effects for the precue types of interest persist across both the solo and group then we would infer that participants did not represent their co-actor’s task as performance is no different to performing half the task alone. Evidence to support co-representation would be reflected in slower responses for these precue types in the group condition compared to the solo condition. 

A similar precuing effect was observed across both the group and solo condition for the *unprepared* precue type which suggests that participants did not represent their co-actor’s task. When the precue conveyed advance information for different fingers of different hands (*neither*), RTs were no different for the group than the solo condition with the exception of the *hand* precue type. Responses were faster for the *neither* precue type than the *hand* precue type in the group condition only which goes counter to the notion of task co-representation.
On a given trial for either one of these precue types, two of the four response positions were highlighted yet participants seemed to respond faster for the *neither* precued type in the group condition. Perhaps participants maintained an intentional mindset to adhere to their task instructions and to focus solely on the response positions they were accountable for. Knowing that the co-actor was assigned to respond to targets that appeared in the “to-be-ignored” response positions may have minimized the need for participants to integrate the predicted responses of the co-actor whereas in the solo condition there was no “one else” to “pick up the slack”, so to speak. Finally, the only consistent findings across the solo and the group condition when the *finger* precue type was presented were faster RTs compared to the *unprepared* precue type and comparable RTs to the *neither* precue type. This is not entirely surprising because there is less response uncertainty for the *neither* precue type (Goodman & Kelso, 1980). In the group condition, there was no advantage for the *full* precue type over the *neither* precue type but in the solo condition it was faster. This finding fits nicely with our thought that in the group condition task pressure was reduced because half the task is being taken care of by a co-actor while in the solo condition one could not help but incorporate prior information about the upcoming response.

What can we conclude about co-representation in a social response-precuing task? The results across the solo and group condition did not provide convincing support that a shared task representation was formed when performing a task which required binary choice responses on the part of both participants. Earlier studies on task sharing distributed two S-R alternatives amongst two participants and found that performance in the group condition strongly resembled those completing the entire task alone (e.g., Sebanz et al., 2003a; Study 5). A more convincing piece of evidence in support of task co-representation was the RT
pattern when participants performed the same single response Go/No-Go task alone; the SE was noticeably absent (see Study 5). The observation of the SE in the group condition has been attributed to the activation of not only one’s own representations of S-R mappings but also that of the co-actor as if they were executing the whole task by themselves. As mentioned above, we did not find any substantial difference in performing one part of the response-precuing task alone or alongside a co-actor. Granted, the pattern of precuing benefits for the solo and group condition are not in line with those described by other studies using the conventional response-precuing task (for a replication see Appendix A) but this is likely attributable to the modifications made to the task. Participants were explicitly told that they were responsible for reacting to targets that appeared in two of the four possible response positions and could ignore targets that appeared in the ‘other’ two response positions. This changed the conditions of the task such that set size was reduced. Our results seem to suggest that the activation of co-representation processes does not occur in a response-precuing task. We propose that any performance differences between the solo and group condition may be attributed to changes in cognitive load which could modify the processing strategies used by participants.

Changes in task demands may impact the cognitive load involved in performing a task. For example, when performing the response-precuing task in the solo condition, participants are instructed to respond to targets that appear in the two leftmost response positions. They are also instructed to ignore any targets that appear in the two rightmost response positions. When performing in the group condition, the task is no different than in the solo condition except that it is being carried out alongside another participant. Participants are still instructed to respond to targets that appear in the two leftmost response
positions but that the co-actor will respond to targets that appear in the other two rightmost response positions. The cognitive load imposed by the former task may necessitate increased mental effort than the latter because participants cannot help but process all the information that the precue provides which leads to poorer performance (i.e., longer RTs). For example, if the unprepared precue type was presented, participants in the solo condition may process all response positions despite only being assigned two of those four response positions thus increasing the cognitive load since the number of elements would be increasing. In the case that participants were presented with that same unprepared precue type in the group condition, cognitive load may have been lowered because there was now a co-actor who was assigned the two “to be ignored” response positions. As such, the processing strategy used by participants adapts to the social context of the task and the responsibilities assigned to those they are interacting with.

Albeit our understanding of the nature of shared representations in joint action continues to advance, we have yet to identify all the necessary preconditions under which these shared representations are formed. Terms such as “unintentionally” and “quasi-automatically” have been used to describe how individuals adjust their behaviour when task sharing (Sebanz et al., 2006a). This gives the false impression that whenever a task is distributed among two (or more) individuals, co-representation will transpire; however, recent studies suggest otherwise. For example, Iani et al. (2012) showed that even when paired participants were responsible for complementary aspects of the joint Simon task, the SSE could be modulated by simply altering the context of the task. While an advantage for corresponding responses was found under the cooperative condition, it was noticeably absent in the competitive condition (cf. de Bruijn et al, 2008; Ruys & Aarts, 2010; Study 2). Wenke
et al. (2011) tested whether participants formed shared representations when performing binary choice go/no-go responses as opposed to single go/no-go responses in a variant of the Eriksen flanker task. Evidence for co-representation would come from any interference that the flanker stimuli imposed on target responses if it signalled the co-actor’s response. They did not find a flanker compatibility effect which meant that shared S-R representations were not formed and subsequently activated in a group binary choice Go/No-Go task. Despite the social context under which these tasks were performed, the absence of any effects demonstrates that it is not a sufficient condition for the automatic generation of shared representations. These null findings substantiated our own failure to provide support in favour for the task co-representation account. As a consequence we have formulated our own alternative explanation for the absence of a SPE in the group condition. We put forth that when performing half of the 4-choice response-precuing task (solo condition) it is difficult to ignore advance information pertaining to the unassigned response positions. In the case that there is another person who is responsible for targets that appear in those unassigned response positions, such as the case in the group condition, then one can concentrate on the task that they have been assigned. This would explain why performance in the solo condition more closely resembles performance of the entire 4-choice response-precuing task and why performance in the group condition resembles the expected results of carrying out half of a 4-choice task.

---

29 Wenke et al.’s (2011) study was a follow-up to Atmaca et al. (2011) in which the Eriksen flanker task was divided between two participants who sat beside each other such that each was making a single response.
Chapter: General Discussion and Conclusion

“We shall not cease from exploration, and the end of all our exploring, will be to arrive where we started, and know the place for the first time.”

T.S. Eliot, Little Gidding V, Four Quartets (1943)

Aristotle’s quote at the introduction of my dissertation expresses how man is naturally sociable. It nicely captures my early acceptance of co-representation as an explanation for the ‘social’ Simon effect (SSE) and as a phenomenon for which cognitive and perceptual processes are influenced by social context. My first two studies, in turn, investigated what task requirements are sufficient preconditions for co-representation. However, as my research progressed I found myself asking whether there were alternative explanation for the SSE. In my last four studies, I began to examine how spatial and response discrimination factors may account for the correspondence effect observed in joint action studies. T.S. Eliot ever so eloquently states that how we learn about life (or, in my case, co-representation) is by way of exploration; exploration provides us with experience and insight. My conception of co-representation has evolved over the series of studies I conducted for this dissertation. Initially, I accepted co-representation as the sole account for the SSE but my findings prompted me to consider that spatial and response discrimination factors could also be contributing to the observed modulations of joint action correspondence effects. As a consequence of my exploration of these factors, I currently find myself not so readily convinced of ‘co-representation’.
We are social creatures; there is no doubt of that. Humans interact with each other. Humans coordinate their actions with each other. Our ability to act with others is an important quality of our species. Thus, it is not surprising that research on joint action has gained momentum over the past decade. A number of studies have replicated the ‘social’ Simon effect (SSE) (e.g., Liepelt et al., 2010; Tsai et al., 2006) and extended (e.g., Atmaca et al., 2008; Hommel et al., 2009; Müller et al., 2011) Sebanz et al.’s (2003a) original findings using similar Simon-like tasks. My first two studies focused on further exploring necessary preconditions for the activation of the co-representation process using a social Simon task.

The presence of the SSE in the group but not the solo Go/No-Go condition is the basis for the argument that co-representation occurs. In the group setting, participants are performing the same Go/No-Go task as they did in the solo setting yet it is as if they were performing the whole task by themselves. Consequently, the observed Simon effect in the group setting is often described as the ‘social’ SE since the change in RT patterns is attributed to the change in social context. Recently, researchers have begun to challenge the claim that the SSE is in fact a ‘social’ phenomenon despite studies that have shown modulations in the SSE when social factors (e.g., interpersonal relations) are manipulated (see Hommel et al., 2009; Müller et al., 2011; Tsai et al, 2007). Even a study conducted by Sebanz and colleagues (2005b) puts into question the influence that social context has on co-representation after they found that a group of autistic participants performed similarly to typically developing participants.30

30 One of the defining characteristics of autism is their difficulty in social interaction (Kanner, 1943).
An alternative explanation for the SSE that is gaining support is the spatial response-coding account for which evidence is found in Guagnano et al.’s (2010) study. They demonstrated that when paired participants performed two independent tasks alongside each other, a small SE was found but only when the participants were within arm’s reach of each other. When the distance between participants extended beyond that, the SE disappeared. If the SSE is truly a social phenomenon then irrespective of the growing distance between the participants, co-representation should have been sustainable. In addition, null findings are now being published from task sharing studies. For example, Wenke et al. (2011) failed to show evidence in favour of co-representation in the context of joint action when participants performed a binary choice go/no-go Flanker task. In Study 3 and 4, we too failed to replicate the SSE described by Sebanz et al. (2003a) in our efforts to test the spatial response-coding account for the joint SE (JSE). Despite finally observing the JSE once again in Study 5, we failed to show similar modulations in the P3 component in the solo and group conditions as described in previous studies (see Sebanz et al., 2006b; Tsai et al., 2006). In Study 6, we seemed to have found a paradigm where task co-representation did not manifest itself in a shared response-precuing task. One explanation is that perhaps a form of ‘social loafing’ (see Latané et al., 1979) was taking place in these dyadic interactions which is in complete contrast to the claim that we, as humans, have a quasi-automatic tendency to co-represent (Sebanz et al., 2006a).

31 In the group condition, participants performed in a non-collaborative task as opposed to a complementary task, which may account for differences in RT patterns. This is discussed in greater detail in Guagnano et al.’s (2010) paper.
9.1 Summary of Conducted Studies

At the outset, my aim was to examine joint action in efforts to understand necessary preconditions under which shared representation are formed. As the findings of my first two studies unfolded, I re-directed my line of studies to test alternative accounts for the joint Simon effect (JSE). More specifically, I examined the spatial response-coding account and later introduced the response discrimination hypothesis as a framework to explain the JSE.

In Study 1, I set out to verify that the SE would not arise under a group condition in which a person would not be expected to form a shared representation of another’s action. Performance in a condition in which both participants responded to the same stimulus-response (S-R) alternative (i.e., both responded to the colour blue with their respective responses) in a joint-action task showed no SSE.

When both participants were responding to the same S-R alternative in Study 1, this may have inadvertently created a setting conducive to competition. To address this matter, we examined joint action in a competitive setting in Study 2 to determine if this had an influence on the formation of shared representations. Participants were explicitly instructed to always try and respond faster than their opponent and a SSE was observed under the competitive context which suggests that individuals co-represent even when it is disadvantageous with respect to the goal of the task.

In Study 3, we set out to examine the possibility that the presence of the co-actor performing alongside the participant induces the spatial coding of responses and this is what gives rise to the SSE, not co-representation. We manipulated the relative spatial position between paired participants by switching their seating position from one joint-action task to
another. We observed no evidence of spatial re-coding which suggest that the SSE does not arise as a result of spatially coding one’s response with reference to the co-actor’s action.

In Study 4, we introduced the response-discrimination hypothesis (RDH) which provides an account for the SE in an individual Go/No-Go task. We examined whether a SE could be elicited in a Go/No-Go task when it was preceded by a Go/No-Go task where the opposite stimulus colour was responded using the opposite response key, a joint action (JA) task, and/or a TC task. We also included a sequence of tasks in which a JA task was followed by a TC task and finished with JA task. Our results showed a SE in a Go/No-Go task when it was preceded by a TC task, as predicted by the RDH. This was not the case when the Go/No-Go task was preceded by a JA task or a Go/No-Go task in which the opposite response key was used to respond to the opposite stimulus colour. This experiment was not without complication as we were not able to replicate the SSE in any of our JA tasks, though the trend toward the SE was in the right direction in one of the sequence groups (i.e., faster RT on corresponding compared to non-corresponding trials). Our failure to consistently replicate the SSE lead us to question whether the social nature of the cueing stimuli (i.e., the pointing finger) typically used (see Sebanz et al., 2003a) induced a larger SSE as it infers ‘your’ turn vs. ‘my’ turn in contrast to non-social stimuli (e.g., asterisks), which did not.

In Study 5, we conducted a replication of Sebanz et al.’s (2003a) original study using finger pointing stimuli as opposed to the simple stimuli in our previous experiments. We found a SSE with a difference of 17 ms between corresponding and non-corresponding trials. We decided to continue using these social cueing stimuli in Study 6 in efforts to ascertain whether the SSE can be observed when paired participants perform independent tasks alongside each other. We observed the SE when the co-actor pressed the opposite response
key but not when the co-actor pressed the same response key as the other participants which suggests that if left-right codes discriminate between alternative responses then the SE can arise. We also replicated the SSE. Our ERP results did not confirm the expected finding that shared representations were formed in the JA task as the group Go-P3 amplitude was smaller than the solo Go-P3 component which implies that there was decreased action-related evaluation of stimuli that referred to another’s action (group condition) than stimuli that did not refer to another’s action (solo condition). It also showed reduced response inhibition in the group condition compared to the solo condition. Similar ERP results were observed when participants performed independent tasks and alternative response keys were assigned to each one. In contrast, when participants performed independent tasks using the same response key, the differences in P3 amplitudes in the solo condition compared to the group condition noted in the JA and the JOK tasks were no longer apparent.

Finally, we explored the notion of shared representations using a different experimental paradigm in Study 7. Using a response-precuing task, we were able to examine performance when participants have two alternative responses at their disposal in the group condition as well as advance information about the required response. The 4-choice task was performed alone, split between two participants and performed alone but with one hand only (making it a 2-choice task). The results from this study did not provide evidence for co-representation when participants engaged in a response-precuing task.
9.2 Another Mind Can Lighten the Load: Why Co-Represent When You Can Have a Free Ride?

At the core of social facilitation theory is that being in the presence of other people has an influence on one’s behaviour (Zajonc, 1965). The idea is that when you are around another person, your arousal increases. An effect of arousal is that you tend to give your dominant response, which is your most common response, in a given situation. For simpler, familiar and well-learned behaviours, the dominant response is to perform well and performance increases when an audience is present. For more challenging, unfamiliar or novel tasks, the dominant response is to perform poorly and mistakes are often made when others are watching (Aiello & Douthitt, 2001; Guerin, 1993). Social facilitation was one of two potential theories that could be used to explain the SSE but was rejected when the SSE disappeared when a confederate sat passively beside participants when the performed the social Simon task alone\(^{32}\) (Sebanz et al., 2003a). The nature of social facilitation seems somewhat passive in the sense that the mere presence of another person can have an impact on behaviour. The ‘other’ person is there but they are not actually engaging in the activity and so the absence of a SSE is not necessarily surprising since it is thought that a shared representation of another person’s action (or task) is formed. Social loafing, on the other hand, describes a phenomenon that occurs when people put in less effort when they are part of a group than when they are working independently (see Latané et al., 1979). Could our failures to replicate the SSE be explained as a kind of ‘social loafing’?

Social loafing captures the idea that effort is reduced when working in a group compared to working alone (Latané et al., 1979). In the case that one can maintain their

---

\(^{32}\) The theory which proved to support Sebanz et al.’s (2003a) findings was the ideomotor theory.
anonymity, social loafing will arise in contrast to when one believes that their performance within the group will be detectable (Williams et al., 1981). People are also more likely to ‘loaf’ if they are in a group made up of strangers than family or friends (Hardy & Latané, 1988). We failed to find evidence in support of co-representation in three of our seven studies (see Studies 3, 4, and 6), could it be that in the solo condition, participants were pressured to discern all aspects of the task (i.e., respond to X, ignore Y) to ensure that they performed the task correctly. After all, they were the only active participant in the task. Once they transitioned to the group condition, they were now performing a complementary task with a co-actor. The co-actor was assigned the responsibility of responding to the stimulus that the participant was asked to ignore and while the co-actor’s task had no direct bearing on the participant’s part of task, a “lightening of the load” could have been inferred. It was our ERP findings in Study 6 that prompted us to consider that participants were taking on an individualistic mindset when completing the task under the group condition.33

Group performance in the response-precuing task (Study 7A) did not support an account of co-representation. We found evidence that counters the notion that in a social setting participants form a shared representation of not only their own but their co-actor’s task. In fact, one might describe the behaviour we observed in the group setting as being very individualistic in nature. When participants completed half of the response-precuing task alone, behaviour was quite similar to performing the entire task alone with the exception that the RTs for the hand and unprepared precue types were similar as well as for the neither and full precue types. When participants performed half the task with a co-actor, the relationship

33 ‘Individualistic mindset’ is one of two terms (the other being ‘collective mindset’) used by cultural psychologists to describe the moral orientation of a society or culture. The term is also used in a branch of research on self-concept structures to describe how the self can be construed. Our use of the term ‘individualistic mindset’ will not correspond to these definitions.
between RT and precue types resembled more of a 2-choice task rather than a 4-choice task, the latter outcome supporting a co-representation account. In the group condition, it was almost as if participants had put on a set of blinders, reducing their cognitive load\textsuperscript{34}. Knowing that the co-actor was required to respond to targets that appeared in the ‘to-be-ignored’ response positions meant that participants could direct their effort on their own part of the task. When performing the task in the solo condition (2-choice task), participants may have been inclined to include the ‘to-be-ignored’ response positions in the stimulus set because it was treated as part of the whole task. Therefore differences in RTs in the group condition seem to reflect a change in set size from four possible response positions to two possible response positions. Whereas the similarity between the RT patterns in the two solo conditions (half and whole) suggest that the tasks were treated no differently. This account would also explain why we may have seen more pronounced No-Go P3 amplitudes in the solo condition compared to the group condition (see Study 6).

Our \textit{individualistic mindset} slant offers a possible explanation for the increased No-Go P3 amplitudes, an indicator of response inhibition, in the solo condition compared to the group condition in both the Joint Action (JA) and Joint-Opposite Key (JOK) tasks. We suggest that in the solo condition, there was increased intentional control to refrain from responding to the no-go stimuli because the constraints set by the task instructions. While the task conditions did not change from the solo to the group condition in the sense that the task remained the same (Go/No-Go), the context that the task instructions were given did. In the solo condition, participants had to respond to one of two stimuli and ignore the other. In the

\textsuperscript{34} According to Sweller (1988), ‘cognitive load’ refers to the amount of mental activity put on working memory at a given time in the context of learning. We use this term in a similar manner but in the context of performance.
group condition, their task was exactly the same as in the solo condition; however, there was now a co-actor who had to respond to the ‘to-be-ignored’ stimuli. We contend that in the group condition, the relevance of the ‘to-be-ignored’ stimulus to the task was downgraded and the demand for intentional control was reduced—they could ‘loaf’ so to speak. Under the new social context, participants re-interpreted the task instructions which affected response inhibition on no-go trials such that it was reduced. The opportunity to implement an individualistic mindset was not a possibility in the solo condition; after all there was no one to take advantage of.

Another factor to consider is that the task was carried out in a laboratory. It may be reasonable to propose that one’s perception of ‘self’ alters when performing a shared task in a ‘controlled’ setting as compared to a ‘natural’ setting. The testing environment (laboratory vs. the real world) may shape whether a participant identifies themself as a ‘player’ in the task or as a sort of neutral ‘entity’. When our participants came in for testing, they completed the Go/No-Go task under the solo condition first, followed by the group condition. Prior to carrying out the Go-No/Go task in the group condition, the co-actor was brought into the testing room, a very brief introduction was made and task instructions were immediately delivered to both parties. It is entirely possible that because our laboratory study did not afford the opportunity for participants to become acquainted and go from being two “strangers” to at least two “players”, an individualistic mindset was induced. As a consequence, the mindset taken by participants in the group condition reduced the need to inhibit their response on no-go trials because those were go trials for the co-actor. In the

35 The experimenter introduced the co-actor and the participant on a first name basis and then outlined the instructions of the task. There was no opportunity for the participants to engage in any conversation to establish much of an interpersonal relationship.
context of social loafing, Holt (1987) has shown that it is possible to prevent the adoption of this mindset if participants are given the time to develop a sense of belonging to a group.

In a recent study by Iani et al. (2011), efforts to identify whether perceived group membership and the strength of in-group and out-group distinction modulated the activation of shared representations yielded supportive evidence in line with our thinking. Despite pairing participants with someone they believed to have either the same or different cognitive style, the SSE emerged under both experimental conditions. In contrast, when interdependence was manipulated such that participants performed the social Simon task under a cooperative vs. competitive condition, the SSE was modulated. In a competitive setting, participants did not co-represent but in a cooperative they did. Iani and colleagues reasoned that the null findings in their first study may be attributed to the fact that social categorization alone was not enough to develop one’s sense of belonging to a group. They concluded that individuals are more inclined to invest in an interaction if there is positive interdependence, giving rise to the activation of shared representations whereas negative interdependence discourages co-representation as one’s competitor is seen as someone impeding them from reaching their task goal and therefore block the integration of self and other’s action. We did not explicitly manipulate group membership in our experiments but we put forth that when there is neutral interdependence, the default process of social categorization is to perceive one’s self as a member of the out-group (i.e., the other group). This would explain why response inhibition may have been required to a lesser degree in the group condition compared to the solo condition in Study 6.

This *individualistic mindset* can be reconciled with the findings of our first two studies in which the SSE was found. In Study 1, responding to the same stimulus-response
(S-R) alternatives in the group condition did not give rise to the SSE. In principle, taking on the proposed *individualistic mindset* would lead to a similar effect when performing the task along with a co-actor. In Study 2, we recognized that responding to the same S-R alternative may have introduced a competitive context to the task and so we tested how competition impacted co-representation. Despite the fact that it may be to one’s advantage to ignore the other’s part of the task, shared representations were still activated and the SSE was observed which has been shown in previous studies (see de Bruijn et al., 2008 and Ruys & Aarts, 2010). Feedback was continually delivered to participant after every trial in order to motivate participants to outperform the other. One of the three solutions thought to reduce the effects of social loafing is to set goals which may inadvertently increase competitive drive (Harkins & Szymanski, 1989). By providing comparative feedback, it is possible that the *individualistic mindset* was suppressed even though a competitive context was established through task instruction (i.e. respond faster than the other person). But how can one be competitive in a task yet identify themselves as being part of a group? What we suggest is that feedback forces participants to be accountable to the task, inhibiting idleness and preventing them from letting their co-actor “lighten the load”. Even though the co-actor is responding to the other stimulus colour, it may be hard for the participant to ignore since *it is* the stimulus that the *competitor* is responding to. The intention of the participant is to outperform the co-actor so perhaps the other stimulus becomes task relevant again. If our line of reasoning is correct then participants should find the *competitor’s* task difficult to ignore as it relays to participants whether they need to try harder; the outcome of this strategy is co-representation (i.e., the observation of the SSE).
How then can we deal with this *individualistic mindset* in the laboratory setting when investigating co-representation in task sharing? This may be a new topic for consideration in joint action research and has not been considered as far as we are aware of. This notion of an *individualistic mindset* necessitates further investigation to determine if it is a potential hypothesis for the null effects that are becoming more prevalent in the literature (see Wenke et al., 2010; Dittrich et al., 2012). Should there be support for the *individualistic mindset* hypothesis then there is definitely the need to examine how this mindset can be deterred in order to better establish the conditions necessary to effectively investigate co-representation in task sharing. One way to do so may be to develop some means of evaluation which does not imply any sense of competitiveness but rather to simply establish a sense of accountability to one’s co-actor when task sharing.

### 9.3 Limitations

We should also stipulate some of the limitations of our studies. First, we were not able to speak to whether one’s level of empathy had any influence on the presence, or absence of a SSE in some of our studies. Empathy can be described as the ability to put oneself in another person’s shoes and to understand and share their feelings (Davis, 1980). Wenke et al. (2011) found that participants who received high empathy scores had a stronger own flanker advantage when performing the task with a co-actor than performing the Go/No-Go task by themselves. The correlation between empathy scores and strength of co-representation would have been an interesting relationship to have considered with respect to some of our null findings. Perhaps our failure to reproduce the SSE could be attributed to the fact that some of our participants did not so readily put themselves in the shoes of others.
Administering an empathy questionnaire, such as the Bamberg Empathy Questionnaire (Enz et al., 2009), which includes not only measures of cognitive and affective empathy but also “ideomotor” empathy would have been beneficial to each of our studies.

Another limitation to our studies was the uncertainty of whether participants believed that the co-actor was truly another naïve participant or a confederate (e.g., research assistant). Participants were never asked at the end of the testing session whether they were wary of who the co-actor was. There is the possibility that if there were any suspicions on the part of the participant that perhaps this would hinder co-representation. We have already described research that found that the co-actor’s disposition can have an influence co-representation (e.g., Hommel et al., 2009). It is possible that if the participant had an inkling that the co-actor was a confederate then they may have deemed them to be untrustworthy or deceitful and in turn processes involved in co-representation may not have been activated. Speaking from a spatial response coding perspective, the spatial response dimension may have been made less salient if the participant perceived the co-actor as being aloof and deceitful (see Dittrich et al., 2012).

Finally, we would also like to recognize the limitation of choosing non-social stimuli (i.e., coloured asterisks) as our experimental stimuli. We had no reason to believe that the SSE would be entirely eliminated by the type of cueing stimuli (i.e., non-social vs. social) used. According to the shared representation account, the SSE is observed because the stimulus-response rules and action plans of the co-actor have been co-represented. We used non-social stimuli as experimental stimuli to explore task co-representation in our first four studies and struggled to consistently find the SSE. Our decision to attempt and replicate the SSE using the same social stimuli (pictures of a pointing finger wearing a colour ring) as in
the original study by Sebanz et al. (2003a) elicited one of our largest SSE. Non-social stimuli
have been used successfully in other joint action studies (e.g., Tsai et al., 2006; Welsh,
2009); however, upon reflection, it may have been in the best interest uniformity to have
used the same social experimental stimuli throughout our studies.

9.4 Conclusion

In closing, we have come to the following conclusions based on the findings that have been
reported in this dissertation about the nature of shared representation and the influence that
task context may have on the modulation of joint action correspondence effects. First, we
found that when responding to the same S-R alternative, the processes involved in co-
representation were not activated which was not unexpected. We also showed that one cannot
help but represent the other person’s task even when it is disadvantageous with respect to the
goal of the task (outperform, or compete against, the other person). Together, these two
findings add to the growing literature on shared representations. Second, we have confidence
that our data from Studies 3-6 strengthens alternative explanations for the findings previously
taken as support for co-representation. Our failure to consistently find the SSE motivated us
to test other factors which may be modulating the joint action correspondence effect.

Although our initial attempt to examine the validity of the spatial response-coding account of
the JSE did not offer the results we anticipated (spatial re-coding), we propose that this may
have been the result of a manipulation that was too disruptive. We subsequently introduced
Ansorge and Wühr’s (2004) response-discrimination hypothesis as an alternative account for
the JSE. Consequently, our preliminary results reinforced the need to further question Sebanz
and colleagues’ interpretation of the SSE. Our final two studies gave us evidence that
participants may be taking on an *individualistic mindset* when engaged in a task alongside another person, irrespective of whether that task is complementary or independent in nature. While considerable evidence has accumulated over the last decade for the activation of shared representation in task sharing, our studies encourage further investigation of how task context modulates the joint action correspondence effect. It also highlights the need to investigate the role that an individualistic mindset may play when performing a task with another individual. And so our exploration continues, just as Eliot articulated.
Bibliography


Appendices

Appendix A  Solo Performance in a 4-Choice Response-Precuing Task

A.1  Introduction

The goal of Study 7 was to establish whether a shared task representation is formed when participants are assigned binary choice responses in a response-precuing task. To address this matter, we had participants perform a modified version of Miller’s (1982) task in which participants were required to make responses to targets that appeared in one of two response positions with the index and middle fingers of their one hand while a co-actor responded to targets that appeared in the other two response positions (Experiment 7A). Originally, we also ran participants through the whole response-precuing task such that they now had to respond to stimuli with responses from the index and middle fingers of both hands in a second testing session. After having collected our data, we recognized the need to test participants in a solo condition in which they performed the exact same task as they did in the group condition of Experiment 7A. In their original study, Sebanz et al. (2003a) compared performance in the Simon task under three different conditions: (1) the 2-choice condition, (2) the group Go/No-Go condition, and (3) the solo Go/No-Go condition. The significance of observing the SE in the group Go/No-Go condition can only be appreciated when one is aware of the typical performance in the solo Go/No-Go condition; there is no SE (cf. Ansorge & Wühr, 2004; Hommel, 1996). A modulation of the SE from the solo condition to the group condition was interpreted as evidence for the representation of another person’s task. Even though we had met the standards of running the response-precuing task through the first two context conditions outlined by Sebanz and colleagues, we overlooked a form of
“solo go/no-go” condition. We could not justify making any inferences about co-representation in the group condition without assessing the pattern of precue benefits when participants perform the identical task alone hence the development of the solo condition described in Experiment 7B.

The results that we present here are the data across all participants in their solo performance of the entire response-precuing task. This task was carried out in the second testing session after they had completed the task under the solo or the group condition depending on which group they had been assigned to. Here we replicate Miller’s (1992) experiment with an additional precue type (full) to ensure that we found the standard precuing effect reported in previous studies (Miller, 1982; Reeve & Proctor, 1984; Adams, 1992).

A.2 Methods

A.2.1. Participants

The participants included all those in Study 7 (Experiment 7A and 7B).

A.2.2. Apparatus.

The apparatus was the same as in Study 7.

A.2.3. Stimuli.

The stimuli were the same as in Study 7.
A.2.2 Procedures

After having completed the task described in Experiment 7A and 7B (see Chapter 8), participants returned for a second testing session to complete the whole response-precuing task alone. The procedures for the present experiment were the same as those described in Study 7 with some slight amendments. Participants were directed to the same seating arrangement originally assigned to them the first testing session and the experimenter explained to them that they would now be making responses with both hands. Participants placed the index and middle fingers of both their hands on the four permissible keys on the response box. Unlike the task performed under the solo and group conditions of Experiment 7A and 7B, participants were instructed to respond as quickly as possible to the target which appeared in one of the four response positions by pressing the appropriate response key. The experimenter reminded participants about the five different precue types and that the precue was 100% valid and to use the information to prepare their response.

A.3 Results

The mean of the RTs across the five precue types are presented Figure A.1. Analysis of the data involved the same criteria used in Experiment 7A and 7B. A one-way repeated measures analysis of variance (ANOVA) on these data of the five Precue types (unprepared, hand, neither, finger, full) showed a significant effect \( F(4, 108) = 26.17, p < 0.01 \). Tukey’s honestly significant difference (HSD) \( p < 0.05 \) procedure was used to conduct post hoc analyses and indicated reliably slower RTs for the unprepared precue type (445 ms) than the other four precue types (389, 389, 387, 322 ms for hand, neither, finger, full, respectively). There was no difference in the RTs for the hand, neither and finger precue types. The full
precue type yielded shorter RTs than the other four precue types. Experimental studies have shown that a modification in the amount of information provided by a precue can increase or decrease performance levels (Goodman & Kelso, 1980; Miller, 1982; Reeves & Proctor, 1984; Rosenbaum, 1980) and these findings are consistent the pattern of differential precue benefits.

Figure A.1 Mean RT for each precue type in the solo condition (4-choice). The SEM for unprepared, hand, neither, finger and full precue types were 18 ms, 17 ms, 18 ms, 16 ms and 16 ms, respectively.

36 The pattern of differential precuing benefits has often showed the ‘hand advantage’ for shorter preparation intervals (i.e., shorter than 1500 ms) but as the preparation interval increases (i.e., 3000 ms) RTs are comparable across the hand, neither and finger precue types (see Reeve & Proctor, 1984). When we refer to the standard pattern of differential precue benefits, we are referring to the findings at longer preparation intervals.