ATTENTIONAL BIASES BY INDUCED MICROVALENCE IN NOVEL OBJECTS: AN EMPHASIS ON THE ROLE OF EXPERIENCE

by

Maria Gloria Mina Manaligod

B.A. The University of British Columbia, 2017

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

August 2020

The following individuals certify that they have read, and recommend to the Faculty of Graduate and Postdoctoral Studies for acceptance, the thesis entitled:

Attentional Biases by Induced Microvalence in Novel Objects: An Emphasis on the Role of Experience

submitted by Maria Gloria Mina Manaligod in partial fulfillment of the requirements for

the degree of Master of Arts

in Psychology

Examining Committee:

Rebecca M. Todd, Psychology
Supervisor

Lawrence M. Ward, Psychology
Supervisory Committee Member

Daniela J. Palombo, Psychology
Supervisory Committee Member

Abstract

How do each of us come to view the world uniquely? An emerging theory of microvalence proposes that subtle feelings of reward and punishment derived from individualized experiences with basic everyday objects help determine how we later attend and behave towards them. These objects that are part of our more mundane experiences are thought to be given attentional priority similar to objects that evoke stronger emotional responses. However, this relationship between preferences guided by daily experience and attention has not been tested. I introduced a novel paradigm to induce microvalences by simulating real life experience paired with an interocular suppression technique (bCFS) to explore its role in attention. Consistent with the theory of microvalence, affective ratings indicated that our novel shapes possessed pre-existing affective properties by which they are evaluated, giving rise to preferences. Unexpectedly, we observed a unifying effect of experience, blurring perceived differences between novel shapes, thus collapsing initial preferences (feelings of like or dislike). Results showed, however, that microvalences were not prioritized in attention. Our findings place emphasis on the role of experience in shifting automatic preferences to create unbiased representations of the world.

Lay Summary

How do experiences with everyday objects shape behaviour? A new theory of *microvalence* suggests that relatively boring objects possess subtle emotional qualities that contribute to why we prefer certain pens over others, or why we avoid using a particular spoon. Further, objects that are part of everyday experiences are thought to grab attention in the same way that strongly emotional objects (e.g., crying babies) do. I tested the relationship between preferences formed from basic everyday experiences and attention and found that people were quick to judge unfamiliar objects on how good or bad they think they were, leading to feelings of like and dislike. Results also showed that experience with these objects diminished these preferences. However, the degree to which they were liked or disliked did not affect how easily they grabbed attention. Our findings highlight the role of experience in changing the emotional relevance of everyday objects for each of us, sometimes reducing pre-existing likes and dislikes.

Preface

The concept and design of the study arose in collaboration with my advisor, Dr. Rebecca M. Todd, post-doctoral fellow Dr. Veronica Dudarev, and PhD student Max Jativa. Data analysis was performed by me with supervision from Dr. R. M. Todd, Dr. V. Dudarev, and Kevin H. Roberts for multi-level model analyses. I was also assisted by Max Jativa for data extraction. Shangjing Hu assisted in programming, and Carina Chen, Jenn McTavish, Christy Chen, Vera Bao, Yan Zhang, Gian Hermosura, Liam Gillanders, Ahmed Shaaban, and Elnaz Ghasemi assisted with data collection.

The project was conducted in the Motivated Cognition Lab in the Department of Psychology at the University of British Columbia with approval from the UBC Behavioural Research Ethics Board (H17-02948).

Table of Contents

List of Tables

List of Figures

Acknowledgements

I thank the Faculty of Arts at the University of British Columbia and the Natural Sciences and Engineering Research Council of Canada (NSERC) for financial support throughout the completion of my Master's program.

I wish to express my deepest gratitude to my advisor, Dr. Rebecca M. Todd, for her unwavering mentorship and trust. I also thank my academic family in the Motivated Cognition Lab, the Vision Lab's post-doctoral fellow Dr. Veronica Dudarev, for their constant support and guidance, Jamie Dunkle and the UBC Psychology IT team headed by Matthew Smith for their painstaking troubleshooting, and my research assistants for their hard work, dedication, and for constantly helping me become a better mentor.

I am eternally grateful for my parents, my *yay*, and my partner, Andrea. You give me strength.

Maraming salamat.

Chapter 1: Introduction

1.1 Review of relevant literature

Day-to-day actions such as grabbing the appropriate coat for the day or, for surgeons, knowing which tool to use during the most crucial moments in surgery are characterized by preferential attention to objects that improve the quality of an intended action. Much as vegetarians filter out meat dishes on a menu to selectively attend to options they can eat, we tend to become more aware of information that is directly relevant to our goals. Selective attention does exactly that – it guides our awareness of the environment so that we prioritize what is important.

Approach of rewarding and avoidance of threatening objects is a highly conserved behaviour observed across species. Objects fairly universally associated with high levels of pain and pleasure, such as guns or flowers, are prioritized in attention, such that we are more likely to become aware of them under conditions where demands on attention are high (Todd & Manaligod, 2017). Thus, in the past, studies investigating effects of affective valence (how good or bad something is, or how much you want to approach or avoid it) on attention have typically involved these extremely emotional objects. Since we rarely encounter such highly emotional objects on a daily basis, they are not necessarily representative of our everyday environments. While there is less likely to be consensus on the objects of preference, many people will report having strong individual preference for mundane items such as a particular pen that is slightly pleasurable or a drinking straw that is mildly aversive. In this case, decisions may be informed by more prosaic experiences so that we may selectively tune our attention to objects that have either been associated with good or bad experiences (Redish, Jensen, Johnson, & Nelson, 2007). It has been proposed that such tuning may arise from repeated experience leading to an accumulation of low-levels of arousal of pain and pleasure. This low modulation of stimulus salience is an example of the formation of *microvalence*, a concept introduced by Lebrecht and colleagues (2012). This theory proposes that less arousing objects (i.e., everyday items) possess subtle affective properties, by which they are slightly “preferred” or “anti-preferred.” Importantly, it has been proposed that these microvalences also guide attentional priorities in a manner similar to more universally emotionally salient stimuli (Todd et al., 2017, Lebrecht, Bar, Barrett, & Tarr, 2012). Yet to our knowledge, this hypothesis has not been directly tested. Thus, the goal of this thesis is to introduce novel methodological approaches to induce microvalences in novel objects and test the hypothesis that stimuli that acquire microvalences for a given individual will guide their attention.

1.1.1 The current landscape of selective attention

Selective attention is the process by which we tune our senses to the world so that information that is most important to us reaches our awareness and guides action. Ongoing in the field is a conversation about whether this tuning can be driven by more basic everyday experiences and are highly dynamic. Classically, modulation of attention has been thought to be characterized by the tension between two clearly delineated control systems: *Top-down* or endogenous processes involving volitional, executive attention to task-relevant stimuli, and *bottom-up* or exogenous processes involving attentional capture by low-level featural salience (e.g., colour, contrast, or motion) (Corbetta & Shulman, 2002; Fox, Corbetta, Snyder, Vincent, & Raichle, 2006). A large body of research in humans and non-human animals has provided support for both attentional systems [e.g., (Desimone & Duncan, 1995; Kastner & Ungerleider, 2001; Reynolds & Chelazzi, 2004)]. Yet the notion of a simple dual process has been challenged. A burgeoning number of cases defying the delineated *top-down* or *bottom-up* processes has led researchers to declare the model as “a failed attentional dichotomy” opening up new avenues for refined models of attention to account for other sources of selection bias (Awh, Belopolsky, & Theeuwes, 2012). They have proposed to expand this framework to include selection history, which emphasizes the role of persisting biases, irrespective of task-related goals and physical salience. Experience, which varies across individuals, is thought to guide attention in a manner distinct from the above-mentioned processes (Lebrecht et al., 2012).

The spatial locations of featurally-salient or goal relevant objects are thought to be represented in priority maps, or topographically organized neural representations within multiple brain regions in both human and non-human animals. Priority maps have been found to guide eye movement such that, for example, neuronal firing in the lateral intraparietal area (LIP) in macaque monkeys predicted saccadic responses (Bisley & Goldberg, 2010). It has been proposed that it is at the level of priority maps that other implicit sources of salience are integrated and work together in guiding attention (Awh et al., 2012, Todd et al., 2017, Chelazzi, Perlato, Santandrea, & Della Libera, 2013, Bisley et al., 2010; Shomstein & Behrmann, 2006; Shomstein & Gottlieb, 2016). Our *priority state space* (PSS) framework proposes that distinct sources of salience are contextually prioritized according to a nested hierarchy of short- and long-term goals creating a spatial and temporal “landscape” that is highly dynamic – constantly adjusting in a span of milliseconds to years (Todd et al., 2017). The recent expansion of the classic model of attention, which initially failed to incorporate discernible influences of history via everyday experiences, has focused on three further sources associated with history that guide attention: statistical learning (predicting events), semantic relatedness (extracting meaning), and reward and emotional salience (approaching pleasure and avoiding pain). Evidence shows that experience-related factors that guide attention extend beyond simple selection bias; thus, we have proposed that selection history, as a third source of salience, should more appropriately be referred to as history (Todd et al., 2017; Kryklywy & Todd, 2018). History then, as we define as the culmination of knowledge, experience, and emotion, serves as a window into what we later prioritize in the environment. Building on Mather and Sutherland's (2011) framework of arousal-biased competition, it has recently been suggested that, counter to previous frameworks outlined by Awh et al., (2012) and ourselves (Todd et al., 2017), history (or selection history) may not be an independent third source of salience that guides attention after all. Rather, it may simply act as a "tuning parameter" of attention by strengthening task-based and featural salience in objects (Kryklywy et al., 2018). However, whether history is a third independent source of attentional guidance or serves to modulate task-based and featural salience remains to be empirically determined.

1.1.1.1 History and reward

How rewarding an object has been in the past defines how we attend and subsequently approach or avoid them in the future. Early work on attention has recognized the role history has played in visual search and various decision-making processes, yet until recently, influences of history were seen as top-down processing operating at an unconscious level (Anderson, Laurent, & Yantis, 2011; Jiang, Swallow, & Rosenbaum, 2013). Reward history has been found to give rise to reflexive ocular movements in tasks where previously rewarded distractors (task-irrelevant) draw attention (Hickey & van Zoest, 2012). Furthermore, incidental learning, or learned probabilities of reward location in space, have long lasting effects (i.e., at least a week) following repeated occurrences (Jiang et al., 2013). Incidental learning, in the lab, has been observed in search tasks where, for example, probability cues such as a target "X" appear in a particular location in the search field for 70% of the time introducing an attentional bias to that location (Jiang et al., 2013). Objects that are semantically related to a previously rewarded object (e.g., a hammer is more related to a baseball bat than lipstick) are also prioritized in busy environments (Shomstein & Behrmann, 2006). Lastly, and most relevant to the present investigation, reward contingencies interfere with top-down and bottom-up attentional systems to gain priority. Previously rewarded distractors have been found to slow search times for relevant targets, trumping both goal-directed and low-level influences (Anderson et al., 2011). Attention guided via unconscious processing of rewarding events has also been observed in brain activity such as suppression in dopaminergic midbrain structures when ignoring previously rewarded distractors, and increased activity in prefrontal regions in the presence of reward (Hickey & Peelen, 2015; Anderson, 2016). As an extension to classical models on which most of what we know about attention is based, these findings show that sources of attentional capture go beyond top-down and bottom-up selection biases. These findings also show that repeated exposure to rewarding events create a persisting influence on attention. This motivated the present study to further probe this phenomenon by looking into how everyday experiences of reward and punishment come together to orient attention and subsequent behaviour.

1.1.2 Selective attention to affective salience

Beyond well-documented prioritization of attention to rewarding objects, we selectively attend to aspects of the environment that are highly emotionally arousing over those that are more mundane (Todd et al., 2017; Markovic, Anderson, & Todd, 2014; Pourtois, Schettino, & Vuilleumier, 2013). This is thought to reflect an evolutionarily conserved motivation to approach appetitive and avoid threatening stimuli. Selective attention also filters out irrelevant information in our surroundings so that those that are relevant to goals related to survival and well-being enter awareness. An instance of this is *affect-biased attention* where emotionally arousing objects are given perceptual priority when cognitive resources are limited (Anderson & Phelps, 2001; Keil, Ibsen, & Heim, 2006; Anderson, 2005; & Raymond & O'Brien, 2009). For example, the attentional blink (AB) phenomenon measures temporal limitations to awareness that are useful for studying attentional prioritization. In AB tasks, when two sequential targets (T1 and T2) are presented in a rapid visual stream within 100-500 ms of each other, participants typically fail to accurately report the second target (T2) (Shapiro, Schmitz, Martens, Hommel and Schnitz, 2006). However, this effect is reduced when T2 contains affectively salient information, suggesting prioritized attention to such information during high attentional demand (Raymond & O'Brien, 2009). Other instances of affective influence on limited cognitive resources are observed in studies using interocular suppression techniques, such as continuous flash suppression (CFS). In CFS, among other masking paradigms, both conscious and unconscious awareness of masked stimuli presented to the nondominant eye are used to measure their emotional significance and how they influence behaviour (e.g., task performance) and emotional states (e.g., mood) (Tsuchiya & Koch, 2006; Lapate, Rokers, Tromp, Orfali, Oler, Doran, Adluru, Alexander, & Davidson, 2016). Negative cues (e.g., fear expressions) compared to neutral cues generate greater amygdala response and modulation of the sympathetic nervous system (e.g., skin conductance response) independent of awareness (Lapate, Rokers, & Davidson, 2014). Additionally, affective stimuli are also perceived with heightened subjective vividness as a result of locus coeruleus-norepinephrine (LC-NE) activity interacting with mechanisms underlying affective salience (Todd, Ehlers, Müller, Robertson, Palombo, Freeman, Levine, & Anderson, 2015).

As the literature reviewed above suggests, reward and emotional salience have similar effects on attention. In fact, they are potentially overlapping categories stemming from different research traditions. Together, these findings show that any object that is part of one's reward history, via spatial location, semantics, or emotional salience, strongly guide attention and influence behavior. Further, these and other studies demonstrate that affective guidance of attention occurs even when the stimulus itself is not consciously perceived (Li, Moallem, Paller, & Gottfried, 2007; Lapate et al., 2014).

Reward history, in this regard, may introduce context-specific salience in objects, which acts to boost task-based or featural salience to tune attention variably in different situations (Mather et al., 2011; Lee, Itti, & Mather, 2012). For example, reward derived from using a thick wool coat during winter may contribute to increase its salience by a) informing its usefulness to provide warmth (top-down) or b) increasing the hedonic value attached to wool vs. polyester in certain contexts (bottom-up).

Beyond evidence that associations with events that are universally rewarding or aversive guide attention, there is some evidence that individually unique experiences do the same. For example, a reduction in the attentional blink, or "emotional sparing" has been found to reflect pre-existing high-arousal experiences with otherwise neutral stimuli (Lee, Todd, Gardhouse, Levine, & Anderson, 2013; Todd et al., 2015). Soldiers deployed in Afghanistan (but not civilian controls) showed emotional sparing for words associated with that particular combat experience (Todd et al., 2015). Passengers on a flight to the Azores that nearly crashed subsequently (but not control subjects) showed emotional sparing for words uniquely associated with this event (Lee et al., 2013). Moreover, evidence also shows that lower-arousal experiences also guide individual attention. Work on rapid hedonic judgment [(e.g., Handy, Smilek, Geiger, Liu and Schooler, 2009)] has suggested that we learn to be guided by emotional associations that are less extreme or dramatic, as well as those that might not even be consciously available at the time. Such evidence outlining the link between affect and attention provides good motivation to test theories such as microvalence, or tuning of attention by low-level reward history, outlined below.

1.1.3 The theory of microvalence

Unlike typical approaches that use strongly emotional events to study valence, the emerging theory of microvalence takes individualized, everyday experiences to investigate how we come to think and behave in the world. According to this theory, a smaller range within the continuum of valence (approach vs avoidance) exists to account for subtle emotional properties imbued in everyday objects (Lebrecht et al., 2012).

Strongly valenced stimuli, such as guns or flowers, give rise to more global emotional responses that overlap between individuals. That is, a negative stimulus (e.g., blood) would likely evoke the same negative feelings in most people. In contrast, everyday objects, such as hairbrushes and pens, are thought to evoke microvalenced responses unique to each individual, custom-tailored from their personal experiences over time. Although we might encounter similar objects in our daily lives, our experiences – whether appetitive or aversive – vary depending on how they serve us at a given time. For example, eating using wooden utensils might evoke positive feelings in one person but negative feelings in another. Similarly, someone might find a heavy porcelain mug more preferable than one made of thin stainless steel. Microvalences are not only interpersonal, but also intrapersonal. Evidence shows that physical properties of objects contribute to the formation of microvalences; For instance, it has been shown that people tend to prefer certain shapes (curved vs sharp edges), material (plastic vs wood), or colour (white vs red) (Lebrecht et al., 2012). However, above and beyond low-level features, the context in which these objects were encountered additionally coloured the objects with positive or negative valence. Such low levels of arousal accrue over time, resulting in a continuous updating of an object’s hedonic value leading to microvalences.

Resulting “attitudes” or affective values associated with objects are then thought to be stored in memory, contributing and further strengthening schemas, to guide future action (Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Lebrecht et al., 2012). Finally, although these evaluations are thought to have a weak signal, and may operate primarily unconsciously, they are thought to contribute to what we come to like (prefer) and dislike (anti-prefer). Importantly, it has been proposed that they guide attention in a manner similar to strongly valenced objects (Lebrecht et al., 2012). Yet to our knowledge, no empirical work has been done to support this claim. Such lack of evidence may stem from experimental challenges in testing this hypothesis. The current study aimed to address this knowledge gap by leveraging several innovative experimental approaches.

Microvalences, as affective properties derived from reward/emotional history, can be thought to provide additional cues for top-down and bottom-up salience to allow for more efficient evaluation of objects in the environment (Mather et al., 2011). By allowing unique experiences to inform low-level features of an object, such that affective salience modulates low-level featural salience (see Mather et al., 2011; Kryklywy et al., 2018), objects may come to possess salience that is highly individualized. That is, each object’s perceptual vividness is weighted differently as a result of varying experiences of reward and punishment between individuals. For example, the experience of a toothache each time a person bites into an apple might lead to increased salience of the hardness of apples. In a similar manner, the same individual buying fruits might shift their attention away from apples because of their painful experiences. Here, hedonic evaluations based on reward history become integrated into one’s mental representation of an object (Lebrecht et al., 2012). Further, this association may transfer to objects that are semantically similar. Microvalences, in this sense, are derived from subtle feelings of reward or punishment associated with an object at a given moment that ultimately give rise to what we consider good or bad. It is also through this process that we can think of how people come to have "favourites" (e.g., a favourite type of pen). Whereas valence typically involves repeated experience of high-arousal pain and pleasure, microvalences involve repeated experience of low-arousal liking (preference) and disliking (anti-preference) (Lebrecht et al., 2012). Given the lower intensity of evoked feelings, it is likely that microvalences require greater repetition to guide attention. However, this claim has yet to be demonstrated.

1.1.4 Continuous Flash Suppression as an index of selective attention

An effective and relatively new masking technique known as *continuous flash suppression* or CFS is used to study visual processing outside conscious awareness and measure selective attention (Tsuchiya & Koch, 2005). It is a stronger form of binocular rivalry which capitalizes on dichoptic stimulus presentation where one eye is presented a static image while a high-contrast dynamic image (e.g., Mondrian patterns) is presented to the other at a steady rate of 10 Hz (Tsuchiya, Koch, Gilroy, & Blake, 2006). As a result of perceptual dominance, static images are rendered invisible by dynamic masks. In many cases, featural, semantic, and affective content of masked stimuli have been found to subliminally prime the individual, influencing task performance (Lapate et al., 2016; Yang, Brascamp, Kang, & Blake, 2014). Among frequently used CFS techniques is *breaking continuous flash suppression* or bCFS wherein a masked stimulus gradually increases contrast over a period of time emerging from suppression (Yang et al., 2016). This technique assumes that certain categories of stimuli (due to their affective and semantic content) break suppression or "pop" into awareness faster than others (Sklar, Levy, Goldstein, Mandel, Maril, & Hassin., 2012; Sun, Cant, & Ferber, 2016). In bCFS studies, the assumption is that objects are processed unconsciously before they become visible, and that unconscious processes detect high-priority objects and deliver them into consciousness faster than neutral ones. In order to measure this, participants are typically asked to press a key to indicate when and where they detect a target.

While consciousness and attention are not synonymous terms, nor are they imperative to one another, they are inextricably linked (van Boxtel, Tsuchiya, & Koch, 2010). Because of strong evidence linking perception to attention, perceptual limitations provided by CFS paradigms makes it a viable measure of selective attention. In particular, breaking time or pop time (as measured in seconds) in bCFS techniques may be a result of faster encoding of certain stimulus categories, which then leads to quicker emergence from suppression and into visual awareness (Yang et al., 2014). Highly affective content of masked stimuli has been found to break suppression faster than their less affective counterparts (Lapate et al., 2016; Yang et al., 2014). In a bCFS task involving semantic processing, sentences that violate one’s semantic knowledge [(e.g., see Sklar et al., 2012)], and negatively-valenced words were also found to break in faster (Sklar, et al., 2012; Yang & Yeh, 2010). CFS proves to be useful in demonstrating how prioritized content influences behaviour by delivering it into awareness sooner. While it is not a direct measure of attention, bCFS is a feasible paradigm for examining potential effects of microvalence on attentional prioritization.

1.2 The present investigation

The present investigation aims to address the knowledge gap on the processes by which microvalences are generated and their role in guiding attention. A look into this phenomenon will provide a crucial window into understanding affective biases in attention by characterizing the role of experience in determining salient aspects of the environment on which we act. We sought to investigate this by employing a *tabula rasa* (blank slate) approach where we induced microvalence in novel objects and subsequently tested their influence on attention. Novel, in this case, pertains to unfamiliar and unconditioned objects. In the literature focusing on microvalence to date, there has been emphasis on the dominating role of experience in forming microvalences (Duckworth, Bargh, Garcia, & Chaiken, 2002; Lebrecht et al., 2012).

To induce and index changes in microvalence in objects, we created a novel paradigm in which participants played a variant of the popular computer game Tetris™. They were instructed to move, rotate, and drop shapes of configurations of blocks to fill in empty spaces in a row of blocks (in a landscape) (see Figure 1). In order to track changes in affect as they accumulated experience, participants were asked to rate each shape on arousal (calm vs excited) and valence (negative vs positive) before and after playing the game, as well as throughout the task. Points were not rewarded so that feelings of reward and punishment developed would be intrinsic to the use of the stimuli. I predicted that microvalence for each shape, if any, would correspond to how useful they were during the task or their gameplay. That is, every action taken to drop a shape to fill a gap – whether successful or unsuccessful – would contribute to changes in positive or negative microvalence.

I sought to investigate hypothesized differences in attentional guidance by employing a pre-post design using bCFS. In each bCFS task, shapes in the microvalence training task served as masked stimuli. I hypothesized that pop times (RT) indicating emergence of shapes from suppression would not differ significantly pre-test. Rather, pop times during post-test would reflect differences reflecting acquired microvalences. Moreover, I hypothesized that if microvalences guide attention, differences in pop time should correspond to the degree to which each shape is microvalenced (i.e., most microvalenced shapes will lead to faster pop times than least microvalenced (neutral) shapes).

1.3 Overview of Experiments

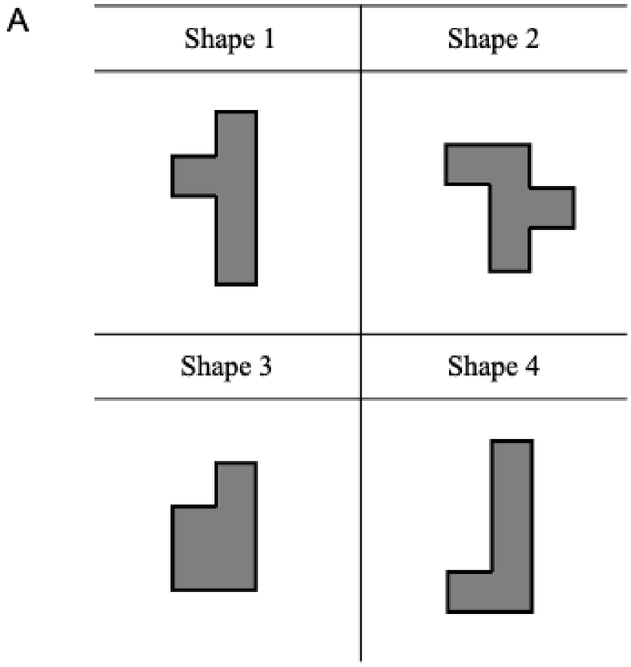
Microvalences are thought to be associated with "high-level" object properties such as conceptual knowledge [(e.g., see Lebrecht et al., 2012)]. However, an overwhelming amount of evidence indicates that low-level properties of objects such as colour and curvature robustly capture attention and contribute to valenced perceptions of objects as well (Theeuwes, 1992, 1994, 2010; Yantis & Jonides, 1984; Desimone et al., 1995; Lebrecht et al., 2012). The following experiments make use of stimuli comprised of basic shapes (i.e., squares). In particular, pentominoes or 5-block Tetris shapes (instead of the 4 or tetrominoes) were used as novel objects. Yet, since it is impossible to control for participants' every experience and/or exposure, there is still the possibility that such shapes can activate pre-existing associations that could later confound any effect on attention. Preferences for objects are often guided by their physical attributes that help determine how pleasant or unpleasant a particular experience will be. For example, a cylindrical drinking glass might be preferable to a square drinking glass as a consequence of a bias towards curved edges (Bar & Neta, 2006). Bias, as mentioned earlier, can also stem from semantic associations and affective salience. Although the shapes used in the experiment were structurally the same, it cannot be assumed that other forms of associations cannot be activated. In order to address this possibility, it was important to examine whether stimuli differed in the degree to which they were prioritized in attention prior to any experience induced by our laboratory training task. In Experiments 1 and 2, I compared each shape's influence on attention with each other shape in a single bCFS task.

The microvalence training task was designed to allow participants to create their own proverbial destiny. Since microvalences are thought to be influenced by every experience, the success with which they utilize each shape should contribute to how they feel towards each one by the end of the task. By assessing rating scales before and after the task, I was able to track whether affective valence changed as a result of this particular experience. In the pre- and post-bCFS tests following training in Experiment 3, I was also able to examine whether these microvalences guided attention.

Chapter 2: Experiments 1 and 2

2.1 Experiment 1

Ahead of the primary investigation of interest, I examined the possibility that shapes used in the task might not be equal in salience. In the initial experiment, the 4 shapes to be used in the main experiment were juxtaposed in pairs in a bCFS task. To compare ‘pop times’ for each pair of shapes, 2 of the 4 shapes were randomly presented as targets in each of 6 experimental blocks (Figure 1B). In this experiment, I made the following assumption: Although unpredictable associations may play into the degree to which each shape is prioritized in attention, the structural similarity of the shapes should lessen any variability between them. Thus, I predicted that there would not be differences in pop times between shapes.



B

Block	Target Stimuli
1	Shapes 1 & 2
2	Shapes 1 & 3
3	Shapes 1 & 4
4	Shapes 2 & 3
5	Shapes 2 & 4
6	Shapes 3 & 4

Figure 1. A. Illustration of the 4 shapes used in the tasks B. Shape pairings in each block in the bCFS tasks

2.1.1 Methods

2.1.1.1 Participants

Forty-four undergraduate students were recruited from the Human Subject Pool of the Department of Psychology at the University of British Columbia and through an online flyer posted on the Paid Participants Studies List (https://gsc.psych.ubc.ca/resources/paid-studies-list). A power calculation conducted using G*Power (Erdfelder, Faul, & Buchner, 2007) indicated that an *N* of at least 34 would be sufficient to detect a medium effect size of 0.5 at a desired power of 0.80, without specifying adjustments for multiple comparisons. Six participants were excluded due to having too few trials (less than 80% of all trials) leaving a total of 38 subjects (29 females, mean age = 21.11 y, SD = 2.44). Participants received 1 course credit or $10 in cash for every 1 hour of testing. The study took approximately 1 hour to complete. Participants were screened for history of seizure or epilepsy and vision problems (e.g., strabismus or amblyopia) and were excluded if these criteria were met. All participants reported having normal or corrected-to-normal vision. All procedures of this study were approved by the Behavioural Review Ethics Board of the University of British Columbia (H17-02948).

2.1.1.2 Apparatus

The experiment was presented on a 24” (1920 x 1080 px) Nvidia 3D monitor that ran on Linux OS (Ubuntu 16.04 LTS). The bCFS task was programmed in MATLAB (R2017b) and presented using the PsychToolbox extension in MATLAB (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007). A chin rest placed at a viewing distance of 53 cm was used to keep the participant’s head steady. Stimuli were viewed using Nvidia 3D glasses to allow monocular presentation of overlapping stimuli.

2.1.1.3 Stimuli

Stimuli consisted of 4 grey (rgb colour code: 127, 127, 127) pentominoes or Tetris-like blocks comprised of 5 blocks. Stimuli in the bCFS tasks were presented at a visual angle of 2.99° and presented in 4 orientations (-90°, 180°, -270°). Each one was created using Adobe Photoshop CS6. Square Mondrian patterns were generated in MATLAB.

2.1.1.4 Procedure

Experimental trials began with a fixation cross followed by a presentation of a static stimulus that faded in gradually from 0-40% contrast for the first 1000 ms. High-contrast dynamic masks consisted of square Mondrian patterns that flickered randomly at a rate of 10 Hz. The masks began to gradually fade out (contrast decreasing to 0%) 7 s into the trial. Participants were asked to respond as soon as they detected any part of the target by pressing the (x) key if the target was below and the right (>) key if it was above the fixation cross. Each trial showed 1 of 2 target shapes and each block showed 2 of 6 counterbalances of shape pairs. There was a one-time practice block containing 20 trials in the beginning of the task. Each block consisted of 80 experimental trials (a total of 480). Each trial ended after a response has been made or until it timed out after 10 s.

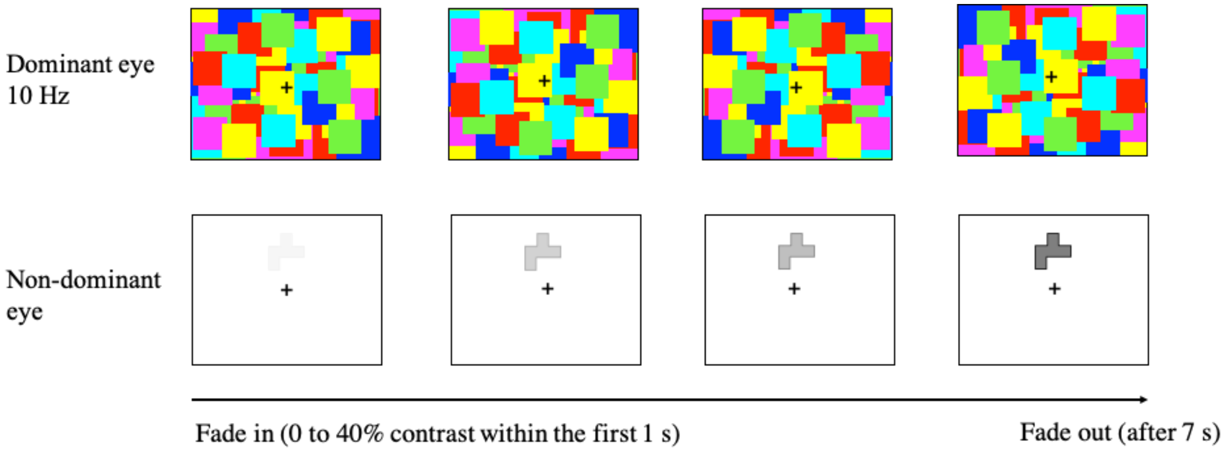


Figure 2. bCFS task schematic with square Mondrian masks (Experiment 1)

2.1.2 Results

Six paired-samples t-tests were performed to compare pop time (RT) between pairs of shapes in each block to investigate potential differences in patterns of attentional prioritization between shapes. Individual trials were aggregated to create columns of pop times by stimulus (regardless of orientation) and block. Incorrect trials and reaction times above or below 3 standard deviations were excluded from analysis. Initially, participants who reported using a 'cheating' strategy (e.g., foveating outside fixation or peripherally, blinking, closing one eye) during the task (16 out of 38 participants) were analyzed separately. However, results for participants who reported 'cheating' strategies did not differ from those who did not, and were thus included in the main analysis. Contrasts were Dunn-Bonferroni corrected for multiple comparisons. RT (in seconds) was slower for Shape 1 than Shape 2, $t(37) = 3.08$, $p = .012$. RTs were also slower for Shape 4 than Shape 1, $t(37) = -2.64$, $p = .036$, and for Shape 3 than Shape 2, $t(37) = -3.16$, $p = .009$. Finally, RTs were slower for Shape 4 than Shape 2, $t(37) = -3.38$, $p = .006$. There were no significant differences between Shapes 3 and 1, and Shapes 3 and 4 (*p*s = 1.00).

See Table 1 for a complete list of results. This experiment revealed differences in pop time between most of the pairs of shapes.

Table 1. Complete results of Experiment 1 (results in bold are significant)

Block	Shape	*Mean (sec)*	*SD*	Shape	*Mean (sec)*	*SD*
1	**1**	**1.47**	**.57**	**2**	**1.38**	**.54**
2	1	1.51	.76	3	1.58	.73
3	**1**	**1.51**	**.63**	**4**	**1.58**	**.73**
4	**2**	**1.55**	**.66**	**3**	**1.65**	**.76**
5	**2**	**1.55**	**.78**	**4**	**1.71**	**.97**
6	3	1.57	.83	4	1.59	.94

2.1.3 Discussion

Results from Experiment 1 revealed differences between shapes without any clear pattern (i.e., no one shape driving the effect) suggesting two possibilities: First, most of the pairs of shapes in the stimulus set were considerably different from each other in the extent to which they were prioritized. Since they were presented independent of any manipulation, other sources of salience such as low-level features and pre-set associations (with the entire object or its parts) could have contributed to why they were prioritized in attention or “popped” sooner. An alternative speculation concerns unexpected interference by square Mondrian masks used. Due to its dynamic nature (i.e., flickering at a rate of 10 Hz), it is possible that the edges of the individual squares inside the mask created a visual illusion and were mistaken as target shapes that also consisted of squares.

2.2 Experiment 2

In Experiment 2, I examined the possibility that the visual interference created by the original square Mondrian masks used in Experiment 1 enhanced visual salience of the square-sided blocks, which reduced the pop time of some shapes. In this study the square masks of Experiment 1 were replaced with round Mondrian masks so that the edges of square masks would not interfere with detection of the block targets. If the pop-out effects observed in Experiment 1 were due to sharp edges enhancing the salience of some targets, replacing them with masks with curved edges should decrease, if not diminish, the effect. Thus, in the experiment with the round Mondrian masks, I again predicted that the shapes would be more or less equally salient as evidenced by equivalent pop times.

2.2.1 Methods

2.2.1.1 Participants

Ninety undergraduates were recruited from the Human Subject Pool of the Department of Psychology at the University of British Columbia and through an online flyer posted on the Paid Participants Studies List (https://gsc.psych.ubc.ca/resources/paid-studies-list). A power calculation conducted using G*Power (Erdfelder et al., 2007) indicated that an *N* of at least 34 would be sufficient to detect a medium effect size of 0.5 at a desired power of 0.80, without specifying adjustments for multiple comparisons. Sample size for Experiment 2 was increased by double in the event that participants who used ‘cheating’ strategies would have to be removed from the analysis. Participants received 1 course credit or $10 in cash for every 1 hour of testing. Eight participants were excluded due to having too few trials (less than 80% of all trials) leaving a total of 82 subjects (66 females, mean age = 22.47 y, SD = 3.41). The study took approximately 1 hour to complete. Participants were screened for history of seizure or epilepsy and vision problems (e.g., strabismus or amblyopia) and were excluded if these criteria were met. All participants reported having normal or corrected-to-normal vision. All procedures of this study were approved by the Behavioural Review Ethics Board of the University of British Columbia (H17-02948).

2.2.1.2 Apparatus

The apparatus used in Experiment 2 were identical to those of Experiment 1.

2.2.1.3 Stimuli

The stimuli used in Experiment 2 were identical to those of Experiment 1 with the exception of the Mondrian patterns generated in the bCFS task. Round Mondrian patterns were used.

2.2.1.4 Procedure

The experimental procedure of Experiment 2 was identical to that of Experiment 1.

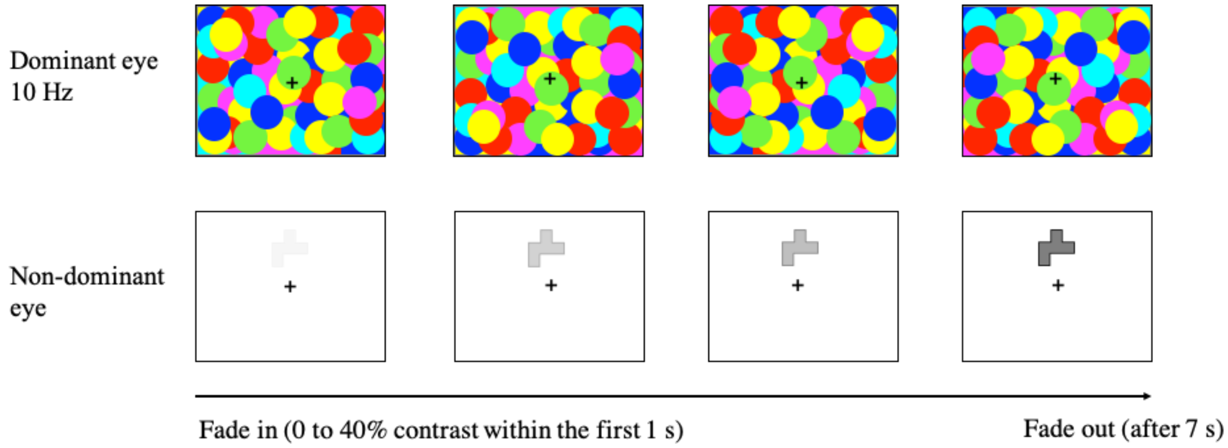


Figure 3. bCFS task schematic with round Mondrian masks (Experiment 2)

2.2.2 Results

The statistical analysis and exclusion criteria were identical to those of Experiment 1. Participants who reported using a ‘cheating’ strategy (31 out of 51 participants) during the task were analyzed separately. The pattern of results for participants who reported 'cheating' strategies did not differ from those who did not, thus they were included in the main analysis. Paired t-tests revealed slower pop time for Shape 4 than Shape 1, *t*(81) = -3.15, *p* = .006, Shape 2, *t*(81) = -3.5, *p* = .003, and Shape 3, *t*(81) = -2.58, *p* = .036. Other shape pairs did not differ in pop-time (*p*s = 1.00). Thus, with round masks, pop times were slower for Shape 4 than for other shapes, suggesting that Shape 4 was considerably less salient.

Table 2. Complete results of Experiment 2 (results in bold are significant)

Block	Shape	*Mean (sec)*	*SD*	Shape	*Mean (sec)*	*SD*
1	1	1.85	1.06	2	1.87	1.11
2	1	1.87	.98	3	1.89	1.04
3	**1**	**1.82**	**.82**	**4**	**1.94**	**1.01**
4	2	1.95	1.04	3	1.97	1.14
5	**2**	**1.97**	**1.14**	**4**	**2.13**	**1.28**
6	**3**	**1.87**	**.93**	**4**	**1.95**	**.99**

2.2.3 Discussion

In Experiment 2, results revealed that replacing square Mondrian masks with round Mondrian masks successfully eliminated differences in pop time between most of the shape pairs observed in Experiment 1. However, experimental blocks that contained Shape 4 did show significantly slower pop time for Shape 4 exclusively. This isolated effect suggests that Shape 4 was significantly less salient than any of the other shapes. Assumptions as to why Shape 4 was less salient than other shapes involve possible influences of low-level features, differences in subjective preferences (i.e., liking) or familiarity (i.e., its similarity to the letter "L").

Although it would have been ideal to use shapes with no difference in initial salience, since the focus of the present study was on changes in salience due to experience, I proceeded with the full investigation. This also allowed for the possibility that the salience of shape 4, which initially differed in from other shapes on average, might become less different with experience.

Chapter 3: Experiment 3

3.1 Materials and Methods

3.1.1 Participants

A total of 99 subjects were recruited from the Human Subject Pool of the Department of Psychology at the University of British Columbia and through an online flyer posted on the Paid Participants Studies List (https://gsc.psych.ubc.ca/resources/paid-studies-list). A power calculation conducted using G*Power (Erdfelder et al., 2007) for a repeated measures ANOVA indicated that an *N* of at least 70 would be sufficient to detect a minimum effect size of 0.17 at a desired power of .80. A small effect size was used to estimate sample size since the effects of microvalence are expected to be more subtle than pop-out effects for one shape vs another we tested in Experiments 1 and 2. Due to technical errors (e.g., MATLAB failing to boot, 3D glasses failing to sync with the IR emitter required for the program to present stimuli dichoptically), 23 subjects were excluded for having incomplete or no data. An additional 7 subjects were excluded for failing to respond to more than 20% of all trials and 2 subjects reported feeling fatigued and falling asleep during the task, leaving data for 67 subjects available for analysis (46 females, mean age = 20.37, SD = 2.66; 8 did not fill out questionnaire). Participants received 1 course credit or $10 in cash for every 1 hour of testing. The study took approximately 2 hours to complete. Participants were screened for history of seizure or epilepsy and vision problems (e.g., strabismus or amblyopia) and were barred from participation if these criteria were met. All participants reported having normal or corrected-to-normal vision. All procedures of this study were approved by the Behavioural Review Ethics Board of the University of British Columbia (H17-02948).

3.1.2 Apparatus

All experimental tasks were presented on a 24” (1920 x 1080 px) BENQ Nvidia 3D monitor that ran on Linux OS (Ubuntu 16.04 LTS). The microvalence training task was run on PyGame (Shinners, 2011), a Python-based computer program for game development. The bCFS task (before and after training) was presented using the PsychToolbox extension in MATLAB (R2017b). A chin rest placed at a viewing distance of 53 cm was used to keep the participant’s head steady. Stimuli were viewed using Nvidia 3D glasses to allow monocular presentation of overlapping stimuli.

3.1.3 Stimuli

Stimuli used in the training and attention tasks consisted of 4 grey (rgb colour code: 127, 127, 127) *pentominoes* or Tetris-like shapes comprised of 5 blocks identical to those used in Experiments 1 and 2. Stimuli in the bCFS tasks were presented at a visual angle of 2.99°. Each one was created using Adobe Photoshop CS6. Pentominoes used in the microvalence training task were subtended at 0.90° per block (each shape consisted of 5 blocks) and generated in PyGame. In both tasks, all stimuli were presented in 4 orientations (0°, -90°, 180°, -270°). Square Mondrian patterns were generated in MATLAB.

3.1.4 Procedure

3.1.4.1 Pre-test bCFS

Experimental trials were identical to those in Experiment 2.

3.1.4.2 Microvalence training

In the microvalence training task, modelled after the popular computer game Tetris™, participants moved, rotated, and dropped slowly falling pentominoes using the keyboard (left, right, up, down keys) to fill gaps in a landscape of blocks. Participants were instructed to complete as many rows as possible. Unlike actual Tetris games where every completed row yields points, points were not given for completed landscapes in this experiment so that any experienced reward or punishment would be intrinsic to use of the stimuli.

The training task had 12 experimental blocks consisting of 5 landscapes. Each landscape had 6 pentominoes for use (excluding a single filler shape used to end each trial) (Figure 4B). The filler shape was used solely for this purpose and was neither rated on arousal and valence nor included as a target in the bCFS task. At the start, after every block, and at the end of training, participants were presented two sliding scales of arousal (calm vs excited) and valence (negative vs positive) on which they rated each shape (in every orientation).

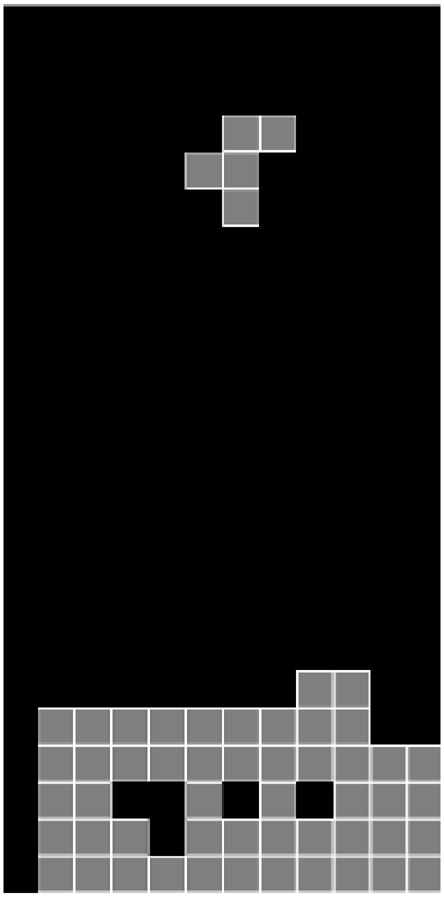


Figure 4. Illustration of a single trial or landscape in the microvalence training task

3.1.4.3 Post-test bCFS

The post-test was identical to the pre-test.

3.2 Results

In the following analyses, incorrect trials and reaction times above or below 3 standard deviations were excluded. In preliminary analyses, data from participants who reported using a strategy (e.g., foveating peripherally or outside fixation, blinking, closing one eye) during bCFS tasks (9 out of 59; 8 did not fill out questionnaire) were analyzed separately. However, as in Experiments 1 and 2, because the pattern of results from ‘cheaters’ did not differ from that of ‘non-cheaters’ all data was combined for analyses reported here.

Primary analyses employed multi-level models using the lme4 package for R (Bates, Maechler, Bolker, & Walker, 2014; R Core Team, 2014) for better parameter estimates using dependency structures and to better account for individual differences, while analyses on secondary measures were conducted using repeated-measures analysis of variance (ANOVA). For all ANOVAs reported, contrasts were Dunn-Bonferroni corrected for multiple comparisons and Greenhouse-Geisser corrected when sphericity was violated.

By the rules of frequentist inference, interpretation of the data must remain within the confines of statistically significant results. However, due to the exploratory nature of the present investigation, nonsignificant patterns of results will be discussed because potential contributions to future research.

3.2.1 Microvalence training

3.2.1.1 Stimulus ratings

Two independent analyses were performed on arousal and valence ratings for each shape collected during the microvalence training task. Analyses of stimulus ratings were carried out to compare potential changes in affective response towards the stimuli before and after repeated experience with them. Raw ratings were normalized such that scores ranged from -100 to 100 (calm – excited, negative – positive) with 0 as the neutral point.

3.2.1.1.1 Arousal

A 2 x 4 (Time x Shape) repeated-measures analysis of variance was performed on arousal ratings collected during the microvalence training task. There was no main effect of time, $F(1,66) = .40$, $p = .532$, $\eta_{p2} = .01$. There was a main effect of shape, $F(2.19,144.46) = 14.00$, $p < .001$, $\eta_{p2} = .18$. Pairwise comparison revealed that Shape 2 was rated most arousing (ps < .001). There was also a time x shape interaction, $F(2.44, 168.51) = 3.09$, $p = .038$, $\eta_{p2} = .43$, showing an overall decrease in variability in arousal ratings for all shapes following training. Post-training contrasts showed that Shape 2 was rated higher in arousal than Shape 4 ($p = .013$). Overall, the greatest shift from high to low arousal was observed for Shape 2. These results suggest that individual shapes differed from each other in arousal pre-training, and that these differences collapsed following experience.

3.2.1.1.2 Valence

The primary index of changes in microvalence associated with each shape was ratings of positive and negative valence before and after training. I applied a random intercept multi-level model to look at the effects of time (pre- and post-training) and shape on liking (rating). The effect of shape differed between the two time points, $F(3, 462) = 19.35$, $p < .001$, $\eta_{p2} = .11$, with a larger effect pre-training, $F(3, 462) = 51.04$, $p < .001$, $\eta_{p2} = .25$, than post-training, $F(3, 462) = 6.41$, $p < .001$, $\eta_{p2} = .04$. Pairwise comparisons showed that ratings for all shapes differed from each other pre-training ($p < .05$), while only ratings for Shape 3 differed from all shapes post-training ($p < 0.05$). The greatest shift from positive to negative valence was observed for Shape

4, *b* = -29.70, *t* = -8.12, *p* < .001. Shape 4 was also most-preferred pre-training (*p* < .001). The variability in valence ratings observed across all shapes pre-training was diminished post-training. Overall, we observed a unifying effect of training suggesting that experiences of intrinsic reward or punishment override any initial preference or anti-preference.

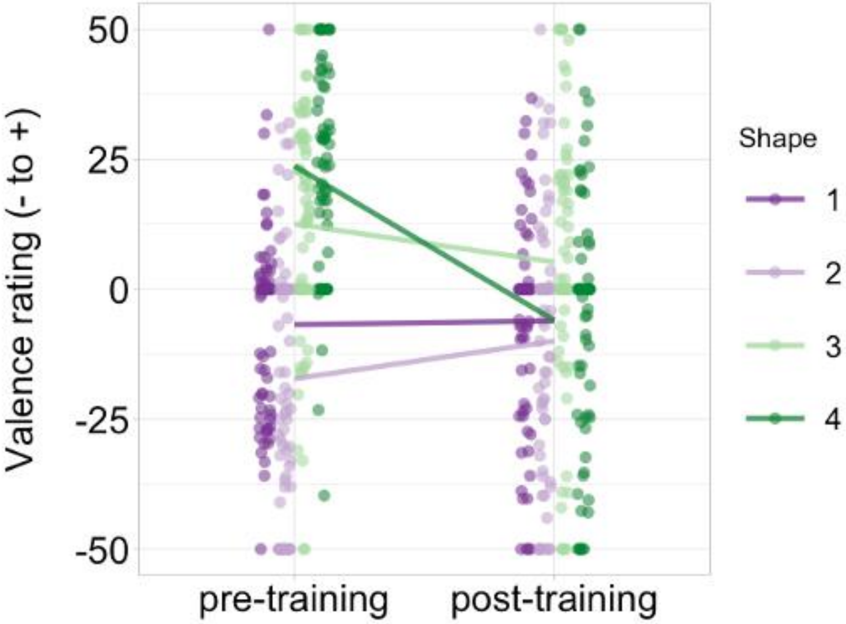


Figure 5. Plot showing greater differences between average ratings pre-training than post training. Predicted average lines for shape ratings show a clear undoing of preference following experience (by training).

3.2.2 Pre-post bCFS

3.2.2.1 Pop Time x Shape

The same random intercept multi-level model was fitted to look at the effects of time (pre- and post-training) and shape on pop time (RT). Overall pop times differed across the two time points, *F*(1, 462) = 250.34, *p* < .001, η_{p2} = 0.35, such that there were faster pop times post-training. However, the effect of shape did not differ between the two time points, *F*(3, 462) =

.18, *p* = .910, η_{p2} = .00. With that said, the greatest difference in pop time from pre-training to post-training was observed in Shape 4.

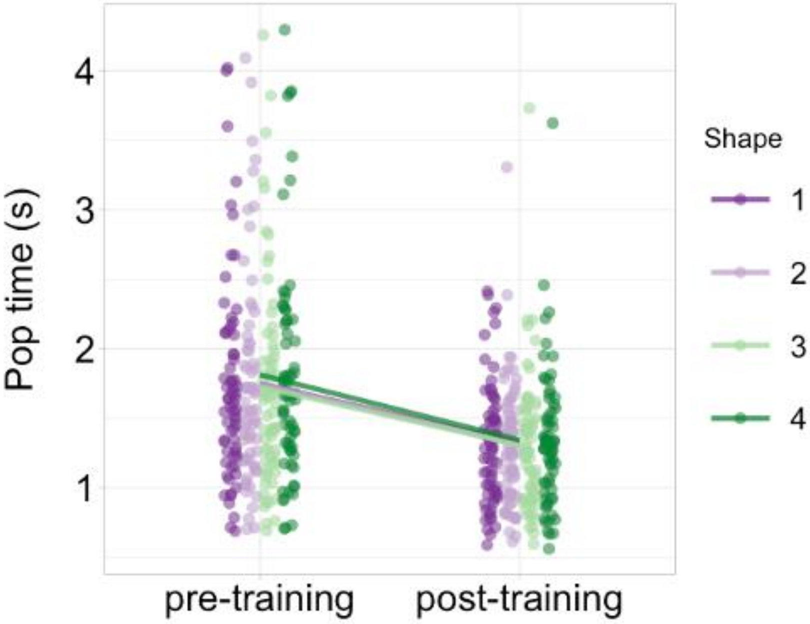


Figure 6. Plot showing a clear effect of time, such that there were faster pop-times post-training. Predicted average lines show no difference in the effect of shape across time.

3.2.2.2 Shape ratings predicting pop time

Next, I tested the hypothesis that changes in valence ratings for each shape would be associated with changes in attentional prioritization. A multi-level model with a random intercept and a random slope for shape ratings (clustered by participant) was fitted to look at the effects of within-subject ratings for each shape on pop time while controlling for time (pre- or post-training) and shape. Results show an overall effect of time, *b* = 3.57, *t* = 6.53, *p* < .001, such that time predicted changes in pop time. The nature of the experiment strongly suggests that this was simply an effect of practice with the bCFS task. No other effect was observed implying that shape ratings do not predict attentional prioritization.

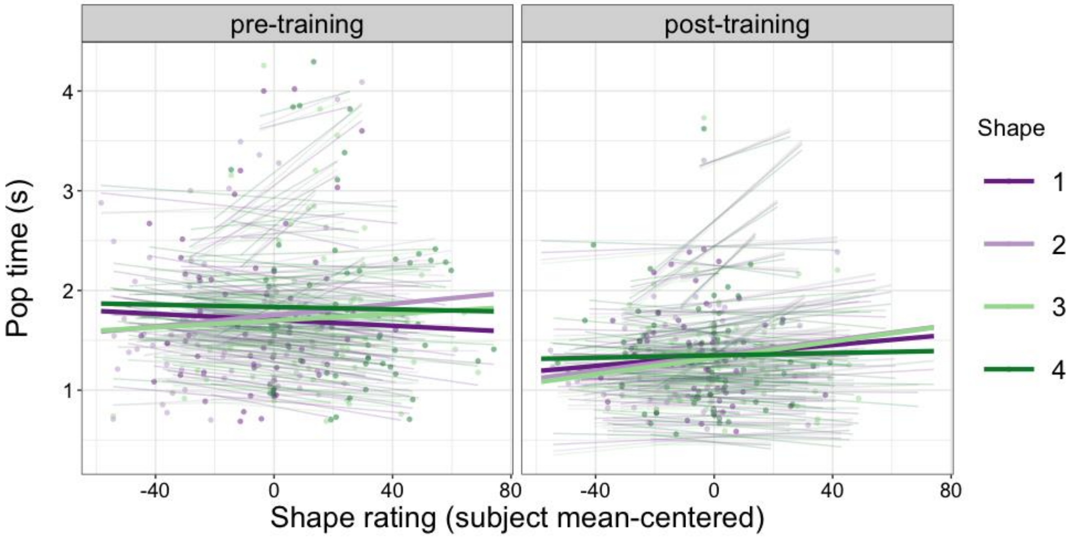


Figure 7. Shape ratings do not predict pop time (RT). Thick lines show predicted group averages for each shape. Thin lines depict the predicted relationship between shape rating and pop time for each shape and participant.

3.2.2.3 Pop Time x Ranking

In this analysis, in order to test the hypothesis that attentional prioritization would be preferentially altered for the stimulus that became more emotionally salient with experience *for each individual*, for each participant I selected the most microvalenced shape (the shape with the greatest *change* in preference) and the most neutral shape (the shape with the least change in preference) based on valence ratings. I then subtracted the initial valence ratings from the final valence ratings (post minus pre). The shape with the greatest rating difference was chosen as the most microvalenced (Rank 1) and the shape with the least difference as neutral (or closest-to-neutral) (Rank 4). A repeated measures analysis of variance was conducted instead of fitting a multi-level model due to multicollinearity between shape ratings and ranking.

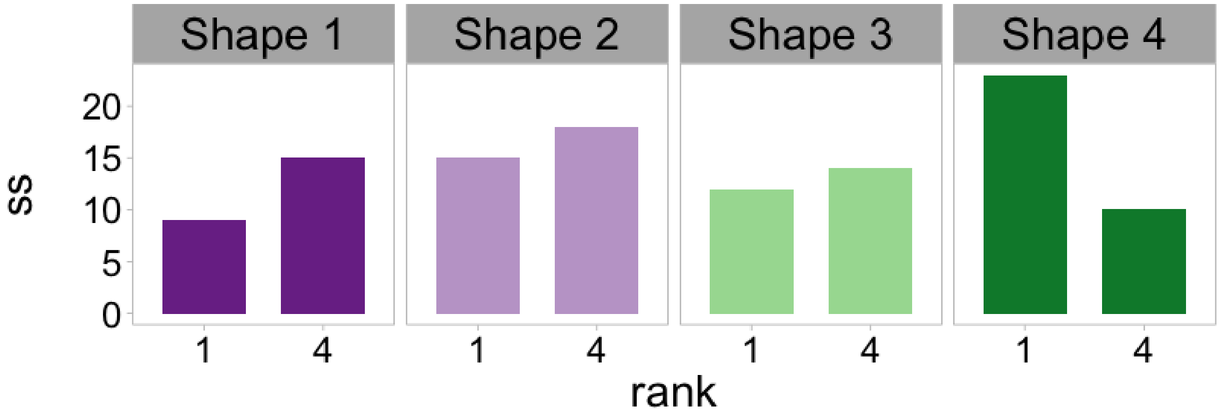


Figure 8. Distribution of designated microvalences for each shape. **y-axis:** participant count

The following repeated-measures ANOVA tested the relationship between ranked microvalenced and neutral shapes, and attentional prioritization via pop time (RT). Not all participants had determinable ranked shapes, thus only 54 out of 67 participants were included in the analysis.

There was a main effect of time, $F(1,53) = 43.51$, $p < .001$, $\eta_{p2} = .45$, with faster pop times post-training. There was no main effect of rank, $F(3, 159) = .76$, $p = .521$, $\eta_{p2} = .01$, and also no hypothesized time x rank interaction, $F(2.37, 125.37) = 1.26$, $p = .291$, $\eta_{p2} = .023$, with clearly no observed differences between rankings (*p*s = 1.00). Thus, contrary to our hypothesis, individually ranked microvalences did not influence attentional prioritization.

In summary, there was no association between shape rating on average for each shape or individual shape change rankings and pop time; however, it is notable that Shape 4, which was rated most positive pre-training — and showed the slowest pop-time in Experiment 2 — showed the greatest change in preference (more negative) and the greatest change (decrease) in pop time in Experiment 3. In order to further illustrate this relationship, I created a dissimilarity matrix (DM) illustrating Euclidean distance (calculated from correlations) between shapes for shape rating and pop time separately (Figure 9). Although purely descriptive, the DMs indicate parallel patterns of greatest dissimilarity between pre and post for Shape 4 for rating and pop time. Such a pattern points to the possibility that, given greater initial valence differences, changes in valence may be accompanied by changes in attentional priority.

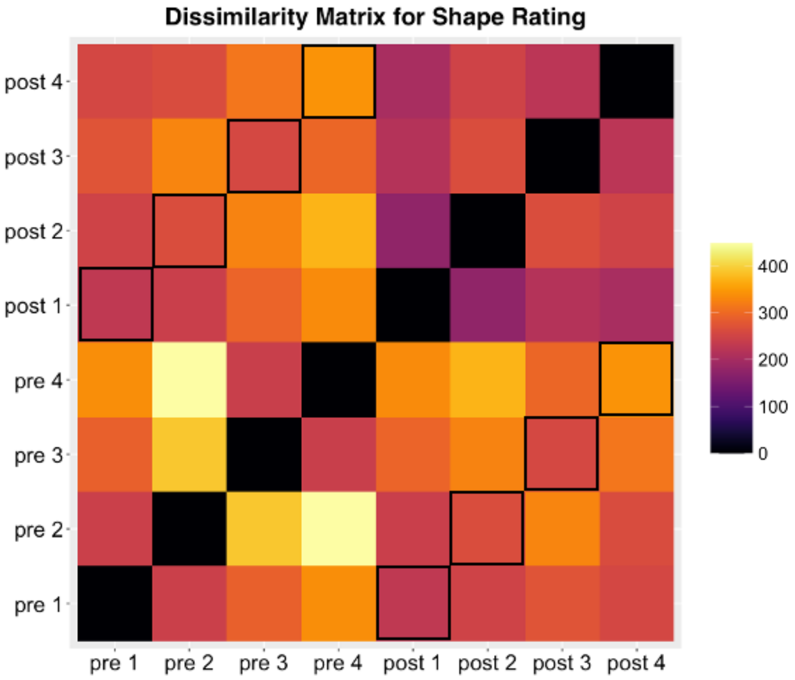


Figure 9. Visualization of greater dissimilarity in liking based on Euclidean distances during pre-training than post-training showing a collapse in preference. Outlined shapes show differences between pre-training and post-training for each shape, with the greatest change observed for Shape 4.

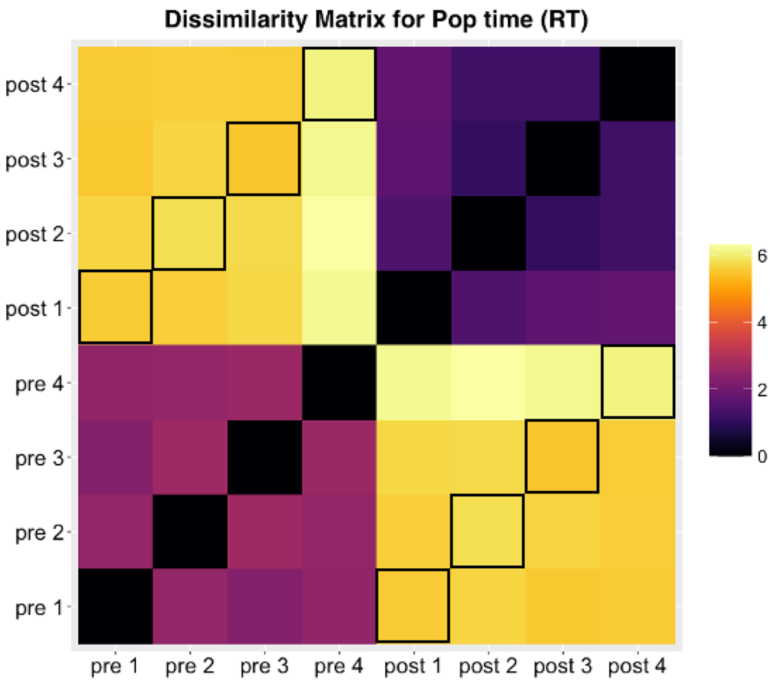


Figure 10. Visualization of differences based on Euclidean distances in pop-time between shapes, with outlined shapes illustrating the greatest difference from pre-training to post-training observed for Shape 4.

3.3 Discussion

Experiment 3 investigated whether and how repeated experience may change microvalenced preferences and whether these play a role in guiding attention. Participants were given freedom to craft their own experiences using novel shapes in a computer game-like task with the objective of filling in as many gaps in a landscape of blocks as possible. Affective ratings collected before and after the task allowed me to tease apart first and final preferences following recent history with the novel shapes. The variability in initial valence ratings between novel shapes suggested that individuals had pre-existing affective associations attached to them prior to any manipulation. Shape 4, in particular, was initially more preferred. Over time, Shape 4 became negatively valenced, implying an undoing of preference by experience. Why Shape 4 was initially more preferred, including potential contributions of low-level properties or familiarity (i.e., semantic associations (e.g., similarity to the letter “L”) requires further investigation. Further, we speculate that utility of each shape in attaining the goal of completing landscapes may have been involved. If preference for Shape 4 was associated with expected utility, the decrease in its valence, bringing it down to par with the other shapes post-training, may suggest that participants found Shape 4 to be no more useful. Nonetheless, the fact that the novel shapes evoked valenced feelings prior to training suggests that they possess subtle affective properties consistent with the conceptualization of microvalence (Lebrecht et al., 2012).

A pre-post experimental design using bCFS allowed me to compare differences in attentional prioritization influenced by microvalences (preferences unique to each individual) and overall liking and disliking of all shapes. Microvalenced shapes (unique to individuals) were not prioritized in attention. There was also no correlation between overall shape ratings and pop time, which in the context of this experiment implies that while overall faster pop times were observed post-training, these were not due to changes in preference. That is, pop times did not reflect the degree to which each shape was liked or disliked.

With regard to arousal ratings, Shape 2 was initially rated as relatively high in arousal prior to any manipulation. While the reason for this remains unclear, this may be attributed to its visual properties such as the number of edges contributing to ‘pointiness’, which has been associated with high arousal (Sievers, Lee, Haslet, & Wheatley, 2019). Although some evidence shows a low correlation between visual complexity and affect, if it in fact is a driving factor in arousal, it must only account for a small portion of other possible influences such as experience or knowledge (e.g., sharp contours perceived as threat) (Madan, Bayer, Gamer, Lonsdorf. & Sommer, 2018; Bar et al., 2006).

In Experiment 3, the failure to replicate the pop-out effect of Shape 4 in Experiment 2 suggests that the results of Experiment 2 were not reliable, potentially due to the relatively small sample size.

Together, the results of Experiment 3 show how experience can shift microvalences by undoing initial preferences. Yet the absence of a clear effect on pop time by both individual microvalences and overall shape preference suggest that, in this experiment, attentional prioritization was not driven by microvalences.

Chapter 4: Conclusion

4.1 Summary of Findings

The present study was designed to examine processes underlying development/changes in microvalences and establish the role of microvalence in attentional guidance. I paired a novel microvalence training paradigm in the form of a computer game-like task with a classic interocular suppression technique, which allowed me to track how individualized affective responses toward novel objects changed with repeated experience and how these were prioritized in attention. My training task revealed a clear undoing of preference following experience, but did not reliably reflect a similar undoing of attentional biases. In contrast to my original prediction, there was no impact of microvalences (designated to each individual) on attentional prioritization. This suggests a limited role of microvalence in guiding attention. The role of microvalences in attentional guidance outside of the present investigation remains unclear.

Although we did not observe the hypothesized effect by which experience-based valenced associations influenced attentional guidance, the results of the present investigation suggest a pattern in which, in some contexts, differences in initial valenced preferences for novel objects are reduced with familiarity and active manipulation. In a simple analogy, many new immigrants face a challenge of adapting to a new environment. Objects in their new surroundings may be highly varied in their emotional content. For example, familiar routes (e.g., around their neighbourhood) (X) will feel secure and are thus approached more, while unfamiliar or novel routes (Y) appear uncertain and are thus avoided. However, time and experience can allow an individual to become more acquainted with the unfamiliar route, obscuring initially perceived differences between X and Y.

While the focus of the present study was originally on the introduction or “doing” of affective biases as a form of learning (i.e., conditioning), I demonstrated that an “undoing” of biases is equally as important in forming meaningful experiences — in valenced preferences, if not in attentional biases.

4.2 Relevance to existing work

A host of information stored in memory, including semantic and contextual knowledge, is automatically activated upon object perception (Lebrecht et al., 2012). In some contexts, familiarity can increase object preference (Reber, Schwarz, & Winkielman, 2004; Kirk, Skov, Hulme, Christensen, & Zeki, 2009). One such study found higher hedonic value attached to abstract paintings presented as a piece from an art gallery (associated with prestige) but not to identical paintings labelled as computer-generated (Kirk et al., 2009). Simple shapes, such as our stimuli, can be judged on valence in a similar manner (Rentschler, Jüttner, Unzicker, & Landis, 1999; Bar et al., 2006; Belin, Henry, Destays, Hausberger, & Grandgeorge, 2017). In the present study, it may be that “L”-shaped Shape 4 was the most familiar to participants. Further, low-level properties of objects have also been found to influence preference reflected behaviourally and on a neural level (e.g., Hu, De Rosa, & Anderson, 2020; Reber et al., 2004; Palmer, Schloss, & Sammartino, 2012). This allows us to infer that while shifts in preference were a result of experience, they were also likely compounded by other associations such as prior experiences and knowledge about the world. In view of this, the present study suggests that a majority of individuals will already have a valenced perception of objects, but that these can also be reversed. To what degree, however, remains unclear.

In the end, while in this study we do not have evidence of the source of differences in valence ratings between shapes, Experiment 3 showed that none of the shapes used were neutral.

Thus, a *tabula rasa* approach where we induce microvalences in valence-free objects, was not possible.

Our manipulation failed to demonstrate the hypothesized attentional guidance by microvalences. A notable observation, however, is that one particular shape that drove changes in preference (from liked to disliked) also showed the greatest increase in salience, although nonsignificantly. This is consistent with work that found increased speed in cognitive processing of disliked objects (as early as 200 ms) (Handy et al., 2009). While we cannot conclude that Shape 4 was indeed *disliked* after some time, it was at the very least *less liked*. The lack of a clear effect on attention is also potentially due to interference from various sources of salience. In this sense, microvalences may not create the same *affect-biased attention* observed in strongly emotional stimuli suggesting that microvalenced objects are not always given perceptual priority. It may also be the case that it is only when a certain level of arousal beyond that which we are characterizing microvalences is evoked that objects are prioritized in attention. This is also congruent with our *priority state space* framework showing how various short- and long-term salience work together in determining how objects are prioritized in attention (Todd et al., 2017). Moreover, history here may have worked as a “tuning parameter” (as described in Kryklywy et al., 2018) that helps modulate task-based and featural salience. Especially in cases where reward and punishment are covert and have a weaker signal, such as in microvalence, the amount of conditioning might not be sufficient to guide attention independently and thus must work in tandem with other sources of salience. One possibility is that, as has been demonstrated for valenced associations (Mather et al., 2011), microvalences can be regarded as qualities of an object that inform both the meaningfulness in relation to goals and the visual vividness of objects, strengthening both top-down (goal relevance) and bottom-up (featural salience) attention. Microvalenced associations, given that they are characterized by lower arousal, may require more repeated experiences, longer consolidation in memory (e.g., sleep) in order to guide attention. Additionally, given the proposal that experience-based affect is highly dynamic, subsequent encounters with valenced objects can be thought to continue to acquire microvalence resulting in a constant updating of one's feelings.

The present results provide basis for speculating that microvalences formed through repeated experience make up a small portion of the many influences on attention. Overall, more work is needed to probe individual effects that either help or hinder attentional prioritization.

4.3 Strengths, limitations, and future directions

How does the present investigation fill the gaps in knowledge? Previous work on affective valence has focused on strongly emotional objects that are not representative of typical everyday experiences. While a few studies have used more basic objects as stimuli [(e.g., see McManus, 1980)], there has been little to no work on how microvalences are acquired and how they relate to attention. Here I attempted to simulate real-life experience by allowing participants to shape their microvalenced attitudes towards novel objects through their own behaviour. To our knowledge, the present study is the first empirical account to do so.

The exploratory nature of the present study does not come without shortcomings and raises several concerns on the validity of the design that may have influenced the pattern of results, or the lack thereof. Theoretically, microvalences are an accumulation of low-arousal experiences with every object formed within a range of milliseconds to years (Lebrecht et al., 2012; Todd et al., 2017). As a result of inter-individual (e.g., history, self-relevance) and intra-individual (e.g., context) differences, no two experiences are alike, and this heterogeneity may create forms of emotion experiences that impact cognition differently (Lambie & Mercel, 2002).

Additionally, even the weak magnitude of microvalences across and within objects may also vary. It is possible that the emotion experience induced by our task due to either stimuli or design (e.g., number of trials/exposure) was not sufficient to observe an effect. Additionally, although our stimuli were structurally similar, notable differences in their physical attributes (e.g., unequal number of edges) may have introduced bias. This highlights the importance of using stimuli that are affectively neutral and equally complex [(e.g., see Madan et al., 2018)] in order to isolate the role of induced emotion experience.

The results of the present study also challenge the notion of ‘neutral’ objects as being completely neutral since what we designate as neutral can be characterized by ambivalence or “mixed feelings”, which have been found to vary in “psychological consequences” (e.g., uncertainty, biases in perception) (Schneider, Veenstra, van Harreveld, Schwarz, & Koole, 2016). Future work should consider incorporating additional measures of attractiveness or aesthetic pleasure, visual complexity, and familiarity to control for object properties that influence both affect and perception, as well as less ambiguous scales (i.e., unipolar instead of bipolar scales of arousal and valence; see Schneider et al., 2016) that more accurately capture emotional experiences (Blijlevens, Hekkert, Leder, Thurgood, Chen, & Whitfield, 2017; Madan et al., 2018; Dobel, Geiger, Bruchmann, Putsche, Schweinberger, & Junghöfer, 2008). By taking neutrality at face value, we are failing to see these small but meaningful differences in emotion that may have a big impact on behaviour.

Further, follow-up experiments (i.e., repeating the experiment using a different set of stimuli) were limited due to the constraints pushed by COVID-19. Future versions of the study will opt to use more homogenous stimuli (i.e., having equal number of edges) as well as consider the aforementioned measures to decrease noise. An immediate course of action concerns a replication of the present investigation using alternative techniques that are less resistant to ‘cheating’. Ideally, eliminating the need for 3D glasses when viewing the task will allow us to employ eyetracking measures to reduce the chance of getting false positives. I am also looking into alternative paradigms that can be conducted remotely to accommodate social distancing measures. Moreover, a quantification of gameplay in order to map each shape’s utility and its relation to microvalence would be of valuable use. If utility were a factor, we can consider questioning whether bases of moment-to-moment ratings of valence varied within and between individuals. That is, valence rating in the beginning of the task may have been based on aesthetic or hedonic valuation, or memory-based utility (how useful it was in the past) whereas valence rating during the task may have been based on moment-based utility (how useful it is now) or aesthetics (e.g., how well it fit the landscape) (Kahneman, Frederick, Fredrickson, Gibson, & Laibson, 2001). The quantifiable differences between post-training and pre-training ratings may be more indicative of total utility and not microvalence. But if, like Edwards (1954), we assign no distinction between utility and valence, which is an overall attitude towards objects or events, then we get rid of the problem of validity. Regardless, when using scales to measure multifaceted concepts such as valence, researchers should clearly state what each scale is trying to capture and explain each end of a spectrum.

Following this, I plan on comparing the effects of microvalence training and high-arousal Pavlovian conditioning on selective attention to explore common or dissociable attentional prioritization processes. Additionally, I will explore how trait motivation to approach or avoid affect between-subject variability in microvalences. Lastly, I plan on investigating neural representations of pleasure and displeasure associated with microvalence and investigate how patterns and strength of hedonic representation of microvalenced objects compare with those of conditioned stimuli.

4.4 Final Remarks

In sum, although more work has to be done to fully understand how microvalences come to be and influence behaviour, the present study hopefully provides a blueprint on which future experimental designs can be based. Our preliminary investigation shows support for the theory that basic everyday objects possess subtle affective properties that may not always be consciously available, but contribute to why and how we find that particular side table at IKEA desirable, or choose a particular paint colour for our bedroom (Lebrecht et al., 2012). Further, we show how experience – whether to introduce or remove biases – can change these preferences, leading to an unbiased view of the world, such as realizing that a $13 vegetable oil in a sparkly tin can is not necessarily better than a $5 one in a tetra pak. Such understanding has implications for neuroeconomics. In particular, this will be useful information for product designers in understanding how consumer experience shapes preference (i.e., implementing user feedback to improve products), as well as the design of workspaces (i.e., classrooms) to facilitate effective working/learning environments.

References

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology General*, 134(2), 258e281. http://dx.doi.org/10.1037/0096-3445.134.2.258, 2005-04168-008 [pii].

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature*, 411(6835), 305e309. http://dx.doi.org/10.1038/35077083.

Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences of the United States of America*, 108(25), 10367e10371. http://dx.doi.org/10.1073/pnas.1104047108.

Anderson, B. A. (2016). The attention habit: How reward learning shapes attentional selection. *Annals of the New York Academy of Sciences*, *1369* (1), 24–39.

Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: A failed theoretical dichotomy. *Trends in Cognitive Sciences*, 16(8), 437e443. http://dx.doi.org/10.1016/j.tics.2012.06.010.

Bar, M., & Neta, M. (2006). Humans prefer curved visual objects. *Psychological Science, 17*(8), 645–648. https://doi.org/10.1111/j.1467-9280.2006.01759.x

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4 [Computer Software].

Belin, L., Henry, L., Destays, M., Hausberger, M., & Grandgeorge, M. (2017). Simple shapes elicit different emotional responses in children with autism spectrum disorder and neurotypical children and adults. *Frontiers in Psychology, 8,* Article 91.

Bisley, J. W., & Goldberg, M. E. (2010). Attention, intention, and priority in the parietal lobe. *Annual Review of Neuroscience*, 33,1e21. http://dx.doi.org/10.1146/annurev-neuro-060909-152823.

Blijlevens, J. & Thurgood, Clementine & Hekkert, Paul & Chen, Lin-Lin & Leder, Helmut & Whitfield, T.. (2017). The Aesthetic Pleasure in Design Scale: The development of a scale to measure aesthetic pleasure for designed artifacts. *Psychology of Aesthetics, Creativity, and the Arts.* 11. 86-98. 10.1037/aca0000098.

Brainard, D. H. (1997) The Psychophysics Toolbox, *Spatial Vision 10*:433-436.

Chelazzi, L., Perlato, A., Santandrea, E., & Della Libera, C. (2013). Rewards teach visual selective attention. *Vision Research*, 85, 58e72. http://dx.doi.org/10.1016/j.visres.2012.12.005.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews. Neuroscience*, 3(3), 201e215. http://dx.doi.org/10.1038/nrn755.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. Annual Review of Neuroscience, 18, 193e222.http://dx.doi.org/10.1146/annurev.ne.18.030195.001205.

Dobel, C., Geiger, L., Bruchmann, M., Putsche, C., Schweinberger, S. R., & Junghöfer, M. (2008). On the interplay between familiarity and emotional expression in face perception. *Psychological Research, 72*(5), 580–586. https://doi.org/10.1007/s00426-007-0132-4

Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli. *Psychological Science, 13*(6), 513–519. https://doi.org/10.1111/1467-9280.00490

Edwards, W. (1954). The theory of decision making. *Psychological Bulletin, 51*(4), 380–417. https://doi.org/10.1037/h0053870

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments & Computers, 28*(1), 1–11. https://doi.org/10.3758/BF03203630

Fazio R. H., Sanbonmatsu D. M., Powell M. C., Kardes F. R. (1986). On the automatic activation of attitudes. *J. Pers. Soc. Psychol.* 50 229–238. 10.1037/0022-3514.50.2.229

Fox, M. D., Corbetta, M., Snyder, A. Z., Vincent, J. L., & Raichle, M. E. (2006). Spontaneous neuronal activity distinguishes human dorsal and ventral attention systems [Research Support, N.I.H., Extramural] *Proceedings of National Academy of Sciences of the United States of America*, 103(26), 10046e10051. http://dx.doi.org/10.1073/pnas.0604187103.

Handy, T.C., Smilek, D., Geiger, L., Liu, C., Schooler, J.W. (2009) ERP evidence for rapid hedonic evaluation of logos. *Journal of Cognitive Neuroscience.* 22: 124-38. PMID 19199410 DOI: 10.1162/jocn.2008.21180

Hickey, C., & Peelen, M. V. (2015). Neural mechanisms of incentive salience in naturalistic human vision. *Neuron*, 85(3), 512e518. http://dx.doi.org/10.1016/j.neuron.2014.12.049.

Hickey, C. & van Zoest, W. (2012). Reward creates oculomotor salience. *Curr. Biol.* 22, R219–R220.

Hu, K., De Rosa, E. & Anderson, A.K. Differential color tuning of the mesolimbic reward system. *Sci Rep* 10, 10223 (2020). https://doi.org/10.1038/s41598-020-66574-w

Jiang, Y. V., Swallow, K. M., & Rosenbaum, G. M. (2013). Guidance of spatial attention by incidental learning and endogenous cuing. *Journal of Experimental Psychology. Human Perception and Performance*, 39(1), 285e297. http://dx.doi.org/10.1037/a0028022.

Kahneman, D., Frederick, S., Fredrickson, B.L., Gibson, L., & Laibson, D. (2001). Experienced Utility and Objective Happiness: A Moment-Based Approach.

Kastner, S., & Ungerleider, L. G. (2001). The neural basis of biased competition in human visual cortex. *Neuropsychologia,* 39(12), 1263e1276. S0028-3932(01)00116-6.

Keil, A., Ibssen, N., & Heim, S. (2006). Early cortical facilitation for emotionally arousing targets during the attentional blink. *BMC Biology*, 4, 23. http://dx.doi.org/10.1186/1741-7007-4-23.

Kirk U, Skov M, Hulme O, Christensen MS, Zeki S. Modulation of aesthetic value by semantic context: an fMRI study. *Neuroimage*. 2009;44(3):1125-1132. doi:10.1016/j.neuroimage.2008.10.009

Kleiner M., Brainard D., Pelli D., 2007, “What’s new in Psychtoolbox-3?” Perception 36 ECVP Abstract Supplement.

Kryklywy, J. H., & Todd, R. M. (2018). Experiential History as a Tuning Parameter for Attention. *Journal of cognition*, *1*(1), 24. https://doi.org/10.5334/joc.25

Lambie, J. A, Marcel, A. J. (2002) Consciousness and the varieties of emotion experience: a theoretical framework. *Psychol. Rev*. 2002;109:219–59.

Lapate, R.C., Rokers, B., Li, T., Davidson, R.J. (2014). Nonconscious emotional activation colors first impressions: A regulatory role for conscious awareness. *Psychological Science,* 25, 349-357.

Lapate, R. C., Rokers, B., Tromp, D. P. M., Orfali, N. S., Oler, J. A., Doran, S., Adluru, N., Alexander, A. L., Davidson, R. J., (2016) Awareness of emotional stimuli determines the behavioural consequences of amygdala activation and amygdala-prefrontal connectivity. *Scientific Reports,* 6, 25826.

Lebrecht, S., Bar, M., Barrett, L. F., & Tarr, M. J. (2012). Micro- valences: Perceiving affective valence in everyday objects. *Frontiers in Psychology*, 3, 107. http://dx.doi.org/10.3389/fpsyg.2012.00107.

Lee, D., Todd R.M., Gardhouse K., Levine B., Anderson, A.K. (2013) Enhanced attentional capture in survivors of a single traumatic event. Paper presented at the Annual Meeting of the Society for Neuroscience, San Diego, CA

Lee, T. H., Itti, L., & Mather, M. (2012). Evidence for arousal-biased competition in perceptual learning. *Frontiers in psychology, 3*, 241. doi:10.3389/fpsyg.2012.00241

Li, W., Moallem, I., Paller, K.A., & Gottfried, J.A. (2007). Subliminal smells can guide social preferences. *Psychological Science, 18,* 1044–1049.

Madan C. R., Bayer J., Gamer M., Lonsdorf T. B., Sommer T. (2018). Visual complexity and affect: Ratings reflect more than meets the eye. *Frontiers in Psychology*, 8, Article 2368. doi:10.3389/fpsyg.2017.02368

Markovic, J., Anderson, A. K., & Todd, R. M. (2014). Tuning to the significant: Neural and genetic processes underlying affective enhancement of visual perception and memory. *Behavioural Brain Research*, 259, 229e241. http://dx.doi.org/10.1016/ j.bbr.2013.11.018

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on psychological science : a journal of the Association for Psychological Science, 6*(2), 114-133. doi:10.1177/1745691611400234

MATLAB 2017b, The MathWorks, Inc., Natick, Massachusetts, United States.

McManus, I.C. (1980), The aesthetics of simple figures. *British Journal of Psychology,* 71: 505-524. doi:10.1111/j.2044-8295.1980.tb01763.x

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2013). Visual aesthetics and human preference. *Annual review of psychology*, *64*, 77–107. https://doi.org/10.1146/annurev-psych-120710-100504

Pelli, D. G. (1997) The VideoToolbox software for visual psychophysics: Transforming numbers into movies, *Spatial Vision 10*:437-442.

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not [Research Support, Non-U.S. Gov't]. *Biological Psychology*, 92(3), 492e512. http:// dx.doi.org/10.1016/j.biopsycho.2012.02.007.

Raymond, J. E., & O'Brien, J. L. (2009). Selective visual attention and motivation: The consequences of value learning in an attentional blink task. *Psychological Science*, 20(8), 981e988. http://dx.doi.org/10.1111/j.1467-9280.2009.02391.x.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience?. *Personality and social psychology review: an official journal of the Society for Personality and Social Psychology, Inc*, *8*(4), 364–382. https://doi.org/10.1207/s15327957pspr0804_3

Redish, A. D., Jensen, S., Johnson, A., & Kurth-Nelson, Z. (2007). Reconciling reinforcement learning models with behavioral extinction and renewal: Implications for addiction, relapse, and problem gambling. *Psychological Review*, 114(3), 784e805. http://dx.doi.org/10.1037/0033-295X.114.3.784.

Rentschler, I., Jüttner, M., Unzicker, A., & Landis, T. (1999). Innate and learned components of human visual preference. *Current Biology*, 9, 665–671.

Reynolds, J. H., & Chelazzi, L. (2004). Attentional modulation of visual processing. *Annual Review of Neuroscience*, 27, 611e647. http://dx.doi.org/10.1146/annurev.neuro.26.041002.131039.

Schneider, I., Veenstra, L., van Harreveld, F., Schwarz, N., & Koole, S. (2016). Let's not be Indifferent about Neutrality: Neutral Ratings in the IAPS Mask Mixed Affective Responses. *Emotion.*

Shapiro, K. L., Schmitz, F., Martens, S., Hommel, B., & Schnitz-ler, A. (2006). Resource sharing in the attentional blink. *NeuroReport*, 17, 163-166.

Shinners, P. (2011). PyGame - Python Game Development. Retrieved from http://www.pygame.org

Shomstein, S., & Behrmann, M. (2006). Cortical systems mediating visual attention to both objects and spatial locations. *Proceedings of National Academy of Sciences of the United States of America*, 103(30), 11387e11392. http://dx.doi.org/10.1073/pnas.0601813103.

Shomstein, S., & Gottlieb, J. (2016). Spatial and non-spatial aspects of visual attention: Interactive cognitive mechanisms and neural underpinnings. *Neuropsychologia*, 92, 9e19. http://dx.doi.org/10.1016/j.neuropsychologia.2016.05.021.

Sievers, B., Lee, C., Haslett, W., & Wheatley, T. (2019). A multi-sensory code for emotional arousal. *Proceedings. Biological sciences*, *286*(1906), 20190513. https://doi.org/10.1098/rspb.2019.0513

Sklar, A., Levy, N., Goldstein, A., Mandel, R., Maril, A. & Hassin, R. R. (2012) Reading and doing arithmetic nonconsciously. *Proceedings of the National Academy of Sciences USA* 109(48):19614–19. Retrieved from www.pnas.org/cgi/doi/10.1073/pnas.1211645109. doi: 10.1073/pnas.1211645109.

Sun, S. Z., Cant, J. S., & Ferber, S. (2016). A global attentional scope setting prioritizes faces for conscious detection. *Journal of Vision*, 16(6):9, 1–13, doi:10.1167/16.6.9.

R Core Team. (2014). R: A Language and Environment for Statistical Computing [Computer Software].

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, 51, 599–606

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: Selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception & Performance* , 20, 799–806

Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica*, 135, 77–99

Todd, R. M., Cunningham, W. A, Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences*, 16(7), 365–72. doi:10.1016/j.tics.2012.06.003

Todd, R. M., Ehlers, M. R., Müller, D. J., Robertson, A., Palombo, D. J., Freeman, N., Levine, B., & Anderson, A. K. (2015). Neurogenetic variations in norepinephrine availability enhance perceptual vividness. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *35*(16), 6506–6516. https://doi.org/10.1523/JNEUROSCI.4489-14.2015

Todd, R. M., & Manaligod, M. G. M. (2017). Implicit guidance of attention: The Priority State Space framework. *Cortex*. doi:10.1016/j.cortex.2017.08.001

Tsuchiya, N., and Koch, C. (2005). Continuous flash suppression reduces negative afterimages. *Nat.Neurosci*. 8, 1096–1101. doi: 10.1038/nn1500

Tsuchiya, N., Koch, C., Gilroy, L. A., & Blake, R. (2006). Depth of interocular suppression associated with continuous flash suppression, flash suppression, and binocular rivalry. *Journal of Vision*, *6*(10), 6. https://doi.org/10.1167/6.10.6.

van Boxtel, J. J. A., Tsuchiya, N., and Koch, C. (2010). Consciousness and attention: on sufficiency and necessity. *Front. Psychol.* 1:217. doi:10.3389/fpsyg.2010.00217

Vuilleumier, P. (2015). Affective and motivational control of vision. *Curr Opin Neurol*, 28(1), 29-35. doi:10.1097/WCO.0000000000000159

Yang, E., Brascamp, J., Kang, M.-S., & Blake, R. (2014). On the use of continuous flash suppression for the study of visual processing outside of awareness. *Frontiers in Psychology,* 5, Article 724. https://doi.org/10.3389/fpsyg.2014.00724

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search.*Journal of Experimental Psychology: Human Perception & Performance*, 10, 601–621.