Using Techniques of Perceptual-Motor Fluency to Influence Preference

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Abstract

Perceptual fluency and response inhibition are established techniques to unobtrusively manipulate preference: objects are devalued following association with disfluency or inhibition. These approaches are extensively studied individually, however, the impact of combining the two techniques in a single intervention is unknown. This thesis investigates manipulations of fluency and inhibition to bias preference. Experiments 1-5 focus on perceptual fluency, examining a new looming motion for its efficacy in eliciting positive and negative affect, and whether this is stored to and retrieved from memory. Experiments 1, 3 and 5 show a robust fluency effect when participants rated the moving stimuli, however, the associative learning of the object-motion pairs is limited and context dependent. Experiments 2, 3, 4 and 5 found that preference judgments of objects rated while static were unaffected by the prior motion of the object, showing a fragile memory effect. Experiments 6-9 test short game-like tasks to examine the preference and memory effects of perceptual fluency and inhibition individually, then the cumulative effects of combining the perceptual fluency, motor-action fluency and inhibition techniques. Experiments 6 confirms that perceptual fluency and inhibition techniques influence immediate preference judgements and Experiment 7 shows combining perception and motor-action fluency has an additive effect on preference bias. Somewhat surprisingly, Experiment 8 shows that combining three techniques together does not lead to greater effects. Finally, Experiment 9 replicated Experiment 8 but with changes to imitate real-world applications: measuring preference after 20 minutes of unrelated tasks, modifying the retrieval context, and generalization from computer images of objects to real-world versions of those objects. Here the individual effects of perceptual-fluency and inhibition were no longer detected, whereas combining these techniques resulted in preference change. These results demonstrate the potential of short video games as a means of influencing behaviour, such as food choices to improve health and wellbeing.

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I, Bryony McKean, declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other University. All sources are acknowledged as References.

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Chapter 1: Introduction

Introduction

As we move through our environment, we are constantly interacting with, attending to and making judgements about the objects around us (Tucker & Ellis, 1998). When making these judgements, we simultaneously have access to both the external information (such as its appearance) and our own internal cognitive processes while encoding the object (Rotter, 1990). Attitudes and preferences can be influenced by these internal cognitive processes, and either the ease or difficulty experienced when processing a given object (Payne, Hall, Cameron, & Bishara, 2010) This process is called perceptual fluency and, in simple terms, the easier an object is to process the more it is preferred by individuals, while the converse is true for objects that are more difficult to process (Reber, Winkielman, & Schwarz, 1998). The influence of perceptual fluency on preference judgements has direct applications in marketing, in particular, brand evaluation (Labroo, Dhar, & Schwarz, 2008; A. Y. Lee & Labroo, 2004; Lee & Baack, 2014) and online shopping experience (Houben, Havermans, Nederkoorn, & Jansen, 2012; Im, Lennon, & Stoel, 2010; Mosteller, Donthu, & Eroglu, 2014; Wang & Ha, 2011). The experiments presented in this thesis manipulate preference using perceptual fluency.

Alongside perceptual fluency, inhibition is also a technique that can be used to manipulate preference. The process of inhibition involves ignoring an object, withholding a response, or refraining from performing a particular behaviour (e.g. Tipper, Driver, & Weaver, 1991) and research has shown that repeatedly inhibiting a response to an object (Frischen, Ferrey, Burt, Pistchik, & Fenske, 2012; Veling, Holland, & van Knippenberg, 2008), or continually ignoring a distractor object (Dittrich & Klauer, 2012), can devalue the target object and produce subjectively lower preference levels. Using inhibition to change preference in this manner has applications in healthcare settings, such as reducing alcohol consumption in problem drinkers (Houben, Nederkoorn, Wiers, & Jansen, 2011), and food consumption in excessive eaters (Houben & Jansen, 2011).

This review will first highlight current methods used to alter health behaviours in children and adults and subsequently form an argument as to why implicit approaches can be used effectivley alongside traditional methodology in a complimentary manner, followed by a short review of the relevant behavioural games currently avalible. For the purpose of this thesis, the definition of implicit is referring to internal processing and cognition that an individual is not consciously aware of (Masson, 1989). The literature relating to both perceptual fluency and inhibition will be discussed and collectivley lead into the present goals and aims of this thesis.

Current interventions for healthy lifestyles

Many of the current interventions targeted at both children and adults focus on explicit approaches aimed at both behavioural changes (e.g. increasing fruit and vegetable intake, decreasing fats and sugar intake), and environmental changes (e.g. increasing availability of healthy foods, increasing exercise, decreasing sedentary behaviours). These approaches explicitly highlight the benefits of a healthy lifestyle (see Haerens et al., 2007; Hardy, King, Kelly, Farrell, & Howlett, 2010). A meta-analysis of such interventions in 26 preschools and kinder gardens (ages 3-6) showed that common initiatives for healthy eating focussed on exposure to fruit and vegetables and outlining nutritional information, such as explicitly informing participants about calories, fat content etc (for a review, see Mikkelsen, Husby, Skov, & Perez-Cueto, 2014). Approaches that aim to increase children's understanding and knowledge of food are considered important because research suggests that children's food preferences are linked to their familiarity with a given food, and an earlier and broader experience of healthy foods can subsequently lead to a more varied diet (Cooke, 2007).

However, the efficacy of explicit approaches alone has mixed results as some research suggests that the longevity of post-intervention behavioural changes can be somewhat limited. For example, in one study a 12-week web and mobile phone-based intervention was created to provide parents information about healthy diet and activity levels for 4 year olds. It was in a one-year post-intervention follow up that no differences in Fat Mass Index (FMI), diet or physical activity levels were present between the intervention and control groups (Nyström et al., 2018). Similar observations have been found in school aged children, for example Deforche, Bourdeaudhuij, Tanghe, Hills, & Bode, (2004) used a residential programme to increase activity levels and reduce calorie consumption in obese children by increasing their exercise levels and implementing a restricted calorie diet for 10 months. During the intervention, obese children showed a significant weight decrease however after 18 months activity levels had regressed back to baseline measures.

Taken together these investigations highlight potential issues with the long-term efficacy of such interventions in children. A number of other research programmes have also shown this same pattern of apparent initial beneficial changes to behaviour, with loss of effects over longer periods (e.g. Fitzgibbon et al., 2011; Kong et al., 2016; Sims, Scarborough, & Foster, 2015; Yavuz, van Ijzendoorn, Mesman, & van der Veek, 2015). Similar findings have been seen in adults with promising short-term effects and weaker long term sustained change (see Samdal, Eide, Barth, Williams, & Meland, 2017 for a review).

While it is clear that conventional explicit methods (such as educating individuals about the content of food, as highlighted above) to address healthy eating have the potential to confer benefits, sustaining meaningful behavioural change in the long-term may require ongoing intervention support or increased parental involvement. Dudley, Cotton, & Peralta, (2015) conduced a meta-analysis on the efficacy of teaching approaches and strategies that promote healthy eating in primary school children. The analysis found that the interventions included a variety of techniques to increase fruit and vegetable intake and decrease consumption of unhealthy foods. The mechanisms of behavioural change in these interventions primarily focussed on the explicit properties of learning (for example, explicitly describing fruit and vegetables as healthy and desirable, and high fat foods as unhealthy and worth avoiding). All interventions had an immediate positive outcome, and increased fruit and vegetable intake in children. However, the most successful interventions were ‘multi-component’ in that they combined explicit knowledge-based and experientially induced learning, suggesting that increasing understanding through teaching alone is perhaps less effective. This observation indicates that perhaps a solution to inducing long-lasting behavioural changes lies in combining intervention techniques to maximise impact. For example, if a fun game was created for children, they may be more likely to engage with it independently and return to it on a daily basis. Such a game could be embedded alongside the more traditional methods highlighted above to encourage ongoing use and induce more constant and long-term benefits.

A second argument for using an implicit approach to converge with an explicit approach is that there can be a mismatch between explicit attitudes, where individuals overtly report their attitudes towards food, and implicit attitudes measured indirectly. For example, in both adults and children, restrained and unrestrained eaters reported the same explicit, self-report attitudes towards food. Importantly, however, implicit association tasks have shown restrained eaters, obese people and those on a restricted diet have stronger automatic approaches (Veenstra & de Jong, 2010), stronger positive liking (Houben, Roefs, & Jansen, 2010; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010), and weaker self-control towards unhealthy, higher calorie food (Maas et al., 2017). These findings were notably absent in the self-report explicit approaches (Craeynest et al., 2005; Veenstra & de Jong, 2010). If healthy and obese individuals have similar explicit attitudes, but their differing behaviours are reflected in implicit processes, then manipulating the latter may be more effective, or at least provide a useful further converging approach.

Apps for behavioural change

As the electronic world continues to grow, and individuals are spending more time using technology, researchers have started to explore the use of games as a tool to change and influence behaviour. Gaming can make mundane tasks more fun and engaging, which, in turn increases the potential compliance with a desired behaviour. Similarly, moving health regulation on to an electronic platform brings with it the opportunity to provide accurate reminders for users.

A meta-analysis looking at gamification for health promotion found that of all the apps available for regulating health in adults, 4% used gamification including techniques such as reward, feedback and monitoring, and goals and planning (Edwards et al., 2016). Perhaps worryingly, a review of 800+ apps designed to reduce alcohol consumption and regulate drinking found that the majority of these apps were not based on scientific research and many both implicitly and explicitly promoted the use of alcohol, which is questionable and dangerous (Crane, Garnett, Brown, West, & Michie, 2015).

Similar observations have been made regarding physical activity apps for adults. One review analysed apps in this area, specifically looking for evidence of the incorporation of scientific behavioural change techniques (Conroy, Yang, & Maher, 2014). Two categories of apps were found to be the most common: educational 'how to' apps and motivational based apps; both of which were limited in their use of behavioural change techniques. A second review on physical activity and dietary apps echoed Conroy et al's (2014) findings, however, paid apps were notably found to incorporate more behaviour change techniques than their free counterparts (Direito et al., 2014).

Lastly, two reviews examining cognitive/brain training through video games and apps revealed that explicit training can increase task specific performance although this increase does not generalise to other aspects of cognition, suggesting that these games are perhaps less effective outside of the context in which they are deployed (Sala & Gobet, 2019; Sala, Tatlidil, & Gobet, 2018). A common thread across these reviews is the critical importance of scientifically validating the effects of the behavioural changes touted by games and apps. Without appropriate scientific appraisal confirming that the intended benefits are transferred across contexts, and over time, the efficacy of a given game or app may be misguidedly limited. Moreover, any claims marketed as such without evidence may be ethically and morally dubious.

Children games for health behaviours and compliance

The research outlined in this section highlights some of the notable studies that explore the promotion of health behaviours through gaming (See appendix 1 for a summary of games and approaches for changing behaviour). Similar to the adult population, apps and games are being used to encourage children to comply with certain behaviours by making them into an enjoyable task. For example, having a playful element when brushing teeth has been found to increase dental hygiene in children. One such game called ‘the virtual aquarium’ had children attach a sensor to the bottom of a toothbrush which was linked to a screen or tablet in the bathroom displaying a scene of a fish tank full of algae and a scrubber brush. When children brushed their teeth, the scrubber would clear away the algae on the inside of the tank and after three minutes, the fish would swim happy in their tank. In this pilot study, all participants increased their brushing time to above three minutes after using the virtual aquarium (Nakajima & Lehdonvirta, 2013). Similar results have been found with a game where children clean a virtual animation of their teeth on screen through the sensor on the end of their toothbrush (Chang et al., 2008).

As well as compliance with hygiene, interactive games have been developed to help children regulate their chronic illnesses such as diabetes (Brown et al., 1997; Lieberman, 2001;Thompson, Baranowski, & Buday, 2010), cerebral palsy (Bryanton et al., 2006) and Sickle Cell disease (Yoon & Godwin, 2007). Incorporating education about health and disease management into a game for children has reduced hospital admissions and increased medicine compliance. Collectively these studies show that games facilitating health-related behavioural change can have a range of benefits for different demographics.

Children games for healthy eating

There are a range of games to encourage children to increase their pallet of food if they are classed as 'fussy eaters', or to consume more fruit and vegetables. These games range from a mix of computer games and board games and feature multiple different techniques, ranging from social modelling to explicit knowledge-based interventions. For example, a pilot study of three children implemented an interactive food game at an outpatient clinic for children who refused to eat certain food types. After three gaming sessions across a year, children increased their repertoire of foods, and as a result had a more balanced diet (Gillis, 2003). This, again, demonstrates the potential benefits of introducing playful elements into interventions intended to increase compliance for certain behaviours. Although Gillis's (2003) work was a preliminary investigation conducted in a clinical setting an interactive video game intended to induce healthy behaviour have reveal the efficacy of this approach.

The video game called 'Squires' Quest' attempted to increase the healthy eating habits of children. In this game children created a 'squire' avatar to look like them who was on a stoic quest for knighthood. To achieve this, they had to overcome challenges, both in the game and real life. Challenges would include daily fruit and vegetable consumption goals, and recipes to make with their parents outside of the game. If players completed these challenges, they received a badge to level up their avatar, where upon their character would learn a new skill to use in the game (Protocol shown in Thompson et al., 2012). Results of the initial study showed that although children increased their intake of fruit and vegetables by one serving per day the intervention did not achieve the goal of five daily portions (Baranowski, Ryan, Hoyos-Cespedes, & Lu, 2019). A follow up study found children who played the game picked healthy snack choices, but more research work was needed to see how the game impacted mealtimes (Cullen et al., 2005). Similar effects have also been extended to board games (Amaro et al., 2006) and interactive mobile phone apps (Pollak et al., 2010).

A systematic review looking at interactive healthy eating and diet games revealed that, while almost all report positive outcomes from playing, the quality of the data collection was somewhat opaque making it difficult to determine whether the results were consistent with true sustained behavioural change (Baranowski et al., 2019). This notion echoes the equivalent literature for adults: if games invoking behavioural change are not based on rigorous science then the efficacy of the any subsequent claims remains inherently limited. Despite this, the above literature on health games for children also shows that implementing health behaviours into games, such as healthy eating and disease management, can increase compliance. Children do appear to respond to fun activities and the continual use of such media may be promising for sustained behavioural change. Conversely, all of the techniques used in the aforementioned games use explicit methods to target behaviours, such as direct education or overt reminders to eat certain foods. The potential for more implicit methods relating to behavioural change therefore remain an underexplored, but potentially promising avenue for inducing desired behaviours.

Perceptual fluency literature

Work exploring the domain of perceptual fluency and its capacity to evoke positive emotions has demonstrated that the properties of certain physical stimuli can subsequently influence how much it is liked. The following section reviews the different ways perceptual fluency can be manipulated to influence preference.

Repeated exposure and presentation time

Early research into object preference has found that mere exposure can induce positive attitudes. For example, repeated exposure to shapes and figures has shown to increase the subsequent appreciation of these stimuli (Bornstein & D’Agostino, 1994). A potential causal factor in this attitude shift is that previously observed stimuli may activate stored representations, inducing familiarity, which in turn facilitates processing thus producing a more positive affect. In a second example, words that were presented more frequently as part of a list received a higher average appreciation score in comparison to words that were presented more infrequently (Zajonc, 1968). As well as increasing stimuli preference, exposure has been found to influence food preferences in both adults and children. Repeated exposure to certain food and drinks has been found to produce higher ratings for these items in parallel with increased consumption and reduced neophobia (Birch & Marlin, 1982; De Wild, de Graaf, & Jager, 2013; Hausner, Olsen, & Møller, 2012; Loewen & Pliner, 1999; Pliner, 1982; Wardle, Herrera, Cooke, & Gibson, 2003). More broadly, exposure to the unfamiliar has also been found to reduce racial prejudice. When white participants were repeatedly exposed to Asian and black faces, positive attitudes towards strangers of that race increased (Zebrowitz, White, & Wieneke, 2008). Similarly, previous exposure has been associated with an increased willingness to help a person (Burger, Soroka, Gonzago, Murphy, & Somervell, 2001), and can make an individual more likely to agree with their judgements (Bornstein, Leone, & Galley, 1987). This research shows that exposure alone as a factor may facilitate preference in conjunction with potential real-world applications beyond laboratory metrics.

Alongside the frequency of exposure, the duration of exposure may also have an impact on appreciation and preference, perhaps through a similar mechanism. Namely, the assumption is that longer presentation or viewing time can allow more familiarity to be established with a given stimulus, which, in turn eases the processing fluency of the object to produce a higher subjective preference (Brieber, Nadal, Leder, & Rosenberg, 2014; Forster, Fabi, & Leder, 2015; Forster, Leder, & Ansorge, 2012; Hamid, 1973). In line with this proposal, in one investigation participants were asked to rate stimuli preference following presentation times ranging from 100 to 400ms. It was found that longer presentation times yielded the highest liking and lowest disliking ratings strongly suggesting even relatively small changes in exposure length can influence preference (Reber et al., 1998).

Symmetry and averageness

An object's symmetry, averageness and familiarity can also facilitate perceptual fluency, which in turn can impact preference and arousal. Symmetrical objects are considered structurally simpler than non-symmetrical objects, potentially making them more efficient and pleasant to process (Bertamini, Makin, & Rampone, 2013; Flavell, Tipper, & Over, 2018; Makin, Wilton, Pecchinenda, & Bertamini, 2012; Pecchinenda, Bertamini, Makin, & Ruta, 2014; Reber & Schwarz, 2001).

In line with subjective appreciation ratings, Makin et al., (2012) explored the neural mechanisms involved in the preference for symmetrical objects using EEG. Participants were asked to classify whether the pattern was random or symmetrical, they were not asked to judge their pattern preferences. Results showed that N1 and P1 spike amplitude was sensitive to all types of symmetry and shapes. However, after the initial N1 and P1 spike, amplitude was higher for random patterns shown through a sustained posterior negativity. This indicates that more attention was required to process the random patterns relative to the symmetrical stimuli, indicating that symmetry could be a key property for regularity-sensitive networks in the visual system. This ease of processing was shown in particular through the lower amplitude when processing the patterns and the Zygomaticus Major (smiling muscle) which manifested greater activation for symmetrical patterns. This latter finding suggests that symmetrical properties may evoke a stronger positive emotional response even when participants are not explicitly judging shapes for preference.

Similarly, symmetry of a person's face is thought to be a biological marker indicating good health, a desirable property when picking a reproductive partner (Rhodes et al., 2001). In one relevant study, a range of faces were averaged together producing greater symmetry and protype representations. The symmetrical faces were judged as healthier than non-manipulated faces, with the latter images being determined as having poorer childhood health. From an evolutionary perspective such judgements may have their origins in determining the fitness in conspecifics given that distinct deviations from facial averageness may provide indicators of chromosomal disorders or health problems to potential mates.

However, further research has shown two things. First, the effects of averaging can be observed across a range of objects, such as cars, birds and fish (Halberstadt & Rhodes, 2003) and with voices (Brucker, Liénard, Lacroix, Kreutzer, & Leboucher, 2006; Watson, Latinus, Bestelmeyer, Crabbe, & Belin, 2012). Second, these preference effects are not just due to symmetry, but rather due to the emergence of an average/prototype image that may be more familiar representation of a class of objects Collectively these results indicate that symmetry and prototypical properties are processed more fluently which in turn can impact judgement across a range of dimensions, such as conspecific attractiveness and the familiarity of animals and objects.

Spatial location

The literature discussed so far involves the manipulation of stimuli appearance to explore object preference, however the spatial location of an object in the visual environment may also be an important factor in this regard. Linguistically, research exploring the meaning of metaphors reveals a degree of truth in the colloquialisms ‘sunny side up’ or ‘cheer up’ as references to positivity. Namely, it has found that the spatial location of a word impact it’s subsequent judgement. For example, when asking participants to evaluate feelings towards ingredients in food items and job roles, it has been found that items were reviewed more favourably when they appeared at the top of the screen (Tourangeau, Couper, & Conrad, 2013). This preference for spatial location is also manifested through processing speed. For example, Meier & Robinson, (2004) found that positively valanced words were more quickly evaluated when presented at the top of the screen while negatively valanced words were judged faster when presented at the bottom. Similarly, when participants were primed to look at the top of the screen, positive words were responded to more quickly while the converse was true for negative words when primed to look at the bottom of the screen.

Consistent with judgements relating to preference, research has also found that vertical spatial location on a screen can influence judgements of power. Across six studies, Schubert, (2005) found that participants deemed that objects that appeared on the top half of the screen were more powerful than objects that appeared on the bottom half. Additionally, objects that were perceived as more powerful were processed and responded to more rapidly when they appeared at the top of the screen relative to the bottom. These results fit with the broader assumption that the higher an object is presented on the screen, the more positively it is evaluated, and that spatial location can influence preference.

Judgements of truth and risk

A parallel line of research has found that individuals draw on fluency to make other decisions, such as judgements of truth, risk and investment value. To determine how fluency can impact judgements of truth, one investigation manipulated sentences by changing the colour of the words against their respective backgrounds. For example, “Lima is the capital city of Peru” was presented to participants in black writing on a white background, which was easy to read (fluent condition) or presented in yellow which was harder to read against the same background (disfluent condition). The sentences in the fluent condition were judged as significantly truer, in comparison to the sentences in the disfluent condition (Reber et al., 1998). This shows that in an ambiguous situation, individuals may draw on fluency to aid their decision making. This result was replicated and extended in a procedure where short (fluent) sentences were judged as more truthful than longer complex (disfluent) sentences (Unkelbach, 2007). The results from these two studies indicate that increased difficulty in reading words or sentences can induce a perception of disfluency which can impact subsequent judgements.

Similar to judgements relating to truthfulness, fluency has been found to impact judgements relating to risk through the pronounceability of words. Across two conditions, Song & Schwarz, (2009) tested subsequent risk ratings of words based on how easy they were to pronounce. In the first condition, participants were asked to rate how risky they thought food additives were on a person's health. It was found that the additives that were easier to pronounce were judged as less harmful, and a lower health risk, than the additives that were harder to pronounce. In the second condition, participants were asked how likely they thought a roller coaster would make them sick by reading the name alone. Results indicated that disfluent, harder to pronounce roller coaster names were judged simultaneously as more likely to make you sick and more dangerous. Similar effects have also been observed in the real-world context of investment in the stock market. That is, more fluently pronounced stock names or ticker codes received greater investments (e.g., Alter & Oppenheimer, 2006; see also Head, Smith, & Wilson, 2009).

Clearly there are a range of perceptual fluency processes that are able to influence preference and choice. Such techniques might be introduced into game environments to influence behaviour. However, a worthwhile further goal is to look for other techniques that might be utilised, and that is one of the goals of this thesis. That is, most previous research has examined the perceptual fluency effects of stationary objects or words. However, motion is also a fundamental property of our visual worlds, as both perceivers and objects move through time and space. Therefore, the relative lack of research on the effects of patterns of motion on object preference brings with it an opportunity to explore this potential factor as part of the agenda of this thesis. Additionally, movement is a property readily used in gaming, and can be easily manipulated methodologically as a technique for shifting preference, hence studies of motion on preference could have additional practical applications.

Inhibition

When moving around our environment, it is impossible to process and attend to everything at once, so we employ selective attention mechanisms to aid us when completing a given task to help reduce the cognitive load (Lavie, 2005). One such mechanism is inhibition which, like perceptual fluency, can be used to manipulate preference. The following section will discuss the research on two types of inhibition; distractor inhibition and inhibition associated with stimuli that have been attended, such as go/no-go and stop signal inhibition.

Distractor inhibition

Early research into target selection and attention has found that distracting images are suppressed and inhibited when trying to find the target image, which in turn decreased the recall of the distractors (e.g. Tipper, 1985; Tipper, Weaver, & Houghton, 1994). This illustrates that distracting objects can be dissociated from attention through the process of inhibition. Raymond, Fenske, & Tavassoli, (2003) tested whether attention could induce emotional responses by asking participants to rate attended polygon patterns, and ignored inhibited pattern, as either ‘cheery’ or ‘dreary’. Results showed that ignored objects were rated more negatively and the target more positively. The key novelty of this finding is that emotive values of objects were affected by the attentional state. Specifically, that ignored objects that were competing for attention were devalued, showing that attention can modulate emotive responses of objects. This process of inhibitory devaluation of distractor objects is a widely accepted view of manipulating preference, and has been heavily replicated with abstract patterns (Raymond, Fenske, & Westoby, 2005) and faces (Fenske, Raymond, Kessler, Westoby, & Tipper, 2005; Goolsby, Shapiro, & Raymond, 2009; Kiss et al., 2007; Raymond et al., 2005). It is also noteworthy that more potent distractors are associated with greater inhibition and devalued more as predicted by reactive inhibition models of attention (e.g., Tipper et al., 1994).

Distractor inhibition has also been applied as a method of therapy in Attentional Bias Modification Treatment (ABMT) for individuals with anxiety through the use of the dot-probe task (Hakamata et al., 2010). This method continually forces participants to draw attention away from, and inhibit, negatively emotional stimuli. Repeated inhibition in this manner has been found to produce a reduction in anxiety symptoms in comparison to control training (Hakamata et al., 2010). That is, individuals who were diagnosed with clinical anxiety no longer met this formal diagnostic criterion following a course of ABMT training (Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015).

In sum, two effects of inhibiting distractors are seen: firstly, inhibition associated with the stimulus can produce a negative assessment of the stimulus and, secondly, the repeated inhibition of negative emotional stimuli can globally reduce negative emotions in participants. This link between stimulus avoidance and affective response provides evidence for a connection between cognition and emotion working simultaneously to ensure the inhibited stimuli are avoided in subsequent encounters.

Go No-Go and stop-signal inhibition

A second technique to implicitly influence emotional reactions is the Go No-Go / Stop signal task. Here participants produce a response for ‘Go’ stimuli and withhold a response for ‘No- Go’ stimuli or withhold a response when a stop signal is intermittently presented simultaneously with the stimuli (Nosek & Banaji, 2001). Go No-Go training has been applied as a method of behavioural change for a range of undesirable behaviours such as excessive alcohol intake and increased food consumption, both of which are influenced by automatic impulses and decreased goal-directed behaviour (Houben, Weirs & Jansen, 2011) Theories relating to problematic alcohol and food consumption propose that these addictions are mediated by two cognitive processes: an associative automatic system and executive control.

Improving inhibitory control may therefore be beneficial in reducing impulsive behaviour towards drinking and eating (Allom, Mullan, & Hagger, 2016; Appelhans et al., 2011; Bechara, 2005; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006).

To this end, Houben, et al., (2011) implemented a Go No-Go task in a sample of excessive drinkers to determine if this reduced impulsive alcohol consumption. Participants in the inhibition training group saw paired pictures of water with ‘Go’ and a ‘No-Go’ response to pictures of alcohol, while the control group performed the opposite. Both groups also performed an implicit association task where they paired beer and water pictures with either pleasant or unpleasant words. Results in the inhibition group showed a decreased positive association and increased negative association for alcohol. Similarly, the inhibition group consumed less alcohol than the control group in the week following the inhibition training. This study has also been replicated and extended by testing inhibitory control abilities where it was found that devaluation of the stimulus was due to evaluative conditioning, and this was not mediated by participants inhibitory control ability (Houben et al., 2012). Similar to Go No-Go training, stop signals have implicitly devalued the ‘attractiveness’ and ‘tastiness’ of food (Veling, Aarts, & Stroebe, 2013) and stop signal training have reduced consumption of high calorie foods such as chocolate and crisps (Veling, Aarts & Strobe, 2013).

The efficacy of Go/No-Go training has been compared with explicit methods such as a brief alcohol intervention (BAI). BAI is where a health professional will encourage an individual to reduce their alcohol consumption if it is posing a risk to their health. Research has found that Go No-Go training is as equally successful as the BAI in decreasing consumption and motivation to drink beer (Bowley et al., 2013), even though BAI works on an explicit level and Go No-go training works on an implicit level. This shows previously desired stimuli can be devalued through the process of Go No-Go response inhibition on both an explicit consumption level and an implicit association level and, moreover, this reduction appears to be as effective as conventional methods. Using a similar paradigm, No-Go training has been found to immediately reduce consumption of chocolate in impulsive chocolate eaters (Houben & Jansen, 2011) and consumption of crisps in students regardless of their eating habits (Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015).

An immediate reduction in food consumption shows that the inhibition training can be proximally successful, however the above studies are cross-sectional in nature and do not measure the longevity of the target behavioural change. One study measured the impact of stop-signal training across a 24-hour period. On day one, half of the participants inhibited responses to sugary foods (test group), and the other half inhibited regular household objects (control group). Both the test and control group contained participants who were either chronic dieters or non-dieters. After the inhibition training, all participants were given a bag of sweets to take home and were instructed to consume as many as they wanted and to bring the remainder back to the lab the next day. It was found that presenting a stop signal near sugary foods reduced chronic dieters' consumption of that food, an effect that was absent in the non-dieters (Veling, Aarts, & Papies, 2011). This finding indicates that stop-signal training had no lasting effect on the general population. Moreover, the results in the dieters' condition could be attributed to the fact they had discussed their diet with a researcher who then gave them a packet of sweets to consume and return the remainder the next day. It therefore remains possible that a desirability bias contributed to the reduction of sweet consumption rather than the inhibition training *per se (*see also Veling, van Koningsbruggen, Aarts, & Stroebe, 2014).

The literature discussed so far highlights the benefits of inhibition regarding a manipulation of preference and that, in comparison to perceptual fluency, inhibition research is embedded in the applied context of behavioural change. Much of this research is focused on clinical populations and there seems to be some ambiguity whether inhibition can change behaviour in the general population. These criticisms are important when considering the research agenda of the present thesis as a key intention is to create a behavioural change technique that is effective in broader population not just clinical or highly motivated samples. Building on this notion, the final section of this review will discuss the research on games created with the intention of changing behaviour.

Goals of the thesis

The above review has made a number of points. First, many of the techniques employed to change behaviour have been explicit. That is, explicitly informing people about the properties of a stimulus, such as calories, fat and/or sugar content; and what behaviours they should change, such as reduce consumption. Although such knowledge-based approaches can have some effects, they have limitations. It was also noted that there are currently a very wide range of existing games that purport to change behaviour, such as increasing exercise, reduced alcohol consumption or the consumption of unhealthy foods. A problem with much of this work is that there is limited and mixed evidence for the effectiveness of the games, and little information concerning the techniques employed.

Therefore, a goal of this thesis is to undertake further studies to provide a foundation from laboratory based basic research that might begin to guide the future use of basic cognitive processes to shift preference and choice behaviour. Existing work has clearly established that both perceptual fluency and inhibition are able to significantly influence preference for a stimulus. The thesis examines this further in two main sections.

First, as noted, most previous research examining perceptual fluency has presented static stimuli. However, motion is also a fundamental stimulus property that could evoke fluent or disfluent processing states. Furthermore, in the context of future game development, motion of objects and game characters is a primary feature of many games, and hence a potential vehicle of biasing preference. Studies will examine, first whether motion fluency effects can be observed, and second, whether associations between an object's identity and its pattern of emotion can be learned and generalise to other stimulus situations. The latter generalisation is critical for broader more applied manipulations of preference change.

The second part of the thesis is, as far as I am aware, one of the first investigations of perceptual fluency and inhibition in the same experimental task, and more importantly, what the effects of combining these mechanisms might be. These studies show that perceptual fluency and inhibition can have rapidly acting and generally quite similar effects on preference change, and that combining these techniques does not always result in more potent effects. However, in more demanding tasks that have greater ecological validity, with generalization to new environments and from computer screen to real objects to be consumed, then combining techniques does indeed make a substantial difference. The results of this research programme provide a first initial step towards identifying what techniques might someday be employed in future game design.

Chapter 2: Motion fluency

Introduction

Perceptual fluency is the subjective feeling of ease or difficulty when processing information (Winkielman, Schwarz, Fazendeiro, & Reber, 2003). There are many manipulations to object properties that facilitate or impede the ease of processing, which can evoke a positive emotive response and impact object preference (e.g., Reber & Schwarz, 2001). For example, higher figure-ground contrast (Reber & Schwarz, 2001; Reber, Schwarz, & Winkielman, 2004), symmetry over asymmetry (Bertamini et al., 2013; Flavell, Tipper, & Over, 2018; Makin et al., 2012; Makin, Pecchinenda, & Bertamini, 2012; Pecchinenda et al., 2014), fluency through pronunciation of words (Alter & Oppenheimer, 2006; Oppenheimer, 2008; Shah, 2007; Song & Schwarz, 2009) are examples of ways to increase preference and liking by facilitating ease of processing.

Research shows that positive emotion can be associated with fluent motor processes. Fluent movements of a body part can be preferred: this is the case for self-produced motor actions and when observing another person's actions (mirror system processes). For example, when participants self-produced an action of grabbing/moving an unobstructed (fluent) or obstructed (disfluent) object, the fluent motor action induced a greater positive affect than the disfluent action. This pattern was also seen when participants merely observed someone completing the action rather than directly interacting with the object themselves (Hayes, Paul, Beuger, & Tipper, 2008). Similarly, research using electromyography found that greater motor fluency in a grab-compatible task, where objects that were placed on the same side of the screen as the grab hand, induced a greater positive physiological response for fluent objects in comparison to the grab-incompatible objects that were placed on the opposite side of the screen to the grab hand, shown through increased zygomaticus major activity (Cannon, Hayes, & Tipper, 2010).

The experiments in this chapter extends the previous work of motion-perception fluency and engages with new issues. Previous research on motion and object preference has shown that certain patterns of motions are preferred (Stevanov, Spehar, Ashida, & Kitaoka, 2012) where symmetrical art preference was enhanced by dynamic motion (Wright & Bertamini, 2015). However, to my knowledge there is no research examining preference for a moving objects identity as opposed to just assessing the motion itself. When assessing an objects identity, previous research has also only manipulated perceptual fluency for preference in the static domain. No current literature is looking at the effect of motion on object judgement where the motion was not assessed, just the object associated with the motion. Motion is a critical property of our environment, that can be used as a technique for manipulating preference and similarly, motion is a property that is readily used in games so effective motion manipulation could be built into the behaviour change game. The aim of the following experiments is to create a robust motion fluency effect that can manipulate preference. The first issue addressed in this chapter is: can the fluency and predictability of an objects motion influence the judgement of an object itself?

Experiment 1

In Experiment 1, a new rotating stimulus is developed to test the efficacy of using motion fluency in shifting preference.

In this task, participants viewed an object rotating and changing size in the centre of the screen. The object was one of four shapes, a square, pentagon, rectangle or triangle, each shape had a unique pattern. The participants' task was to press a button if the object changed from colour to greyscale at any point during its rotation. There were two types of movements: a fluent rotation where the object moved in a smooth and predictable way and a disfluent rotation where the object moved in a non-smooth and unpredictable way. Participants were asked to rate how much they liked each of the objects and the objects motion was not explicitly mentioned. I predict that preference will be higher for the fluent over the disfluent moving objects.

Method

Apparatus

Participants were seated at a table in a dimmed room in front of a 27" touch screen monitor (Iiyama (Tokyo, Japan) ProKite T2735MSC-BZ, 1920 x 1080 pixels) at a distance of 60cm. A keyboard was positioned on the table in between the participant and the screen. A PC (Round Rock, USA) XPS, Intel ® Core (™) i5- 4430, 3 GHz CPU, 12GB RAM, 64 bit Windows 7) generated the stimuli and recorded participant responses. Experiments presented stimuli at 60Hz. All experiments were executed using custom scripts and Psychtoolbox 3.0.11 (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997) operated within Matlab R2017a (The MathWorks Inc., Natick, USA).

Stimuli

The stimuli were four objects; a square, rectangle, triangle and a pentagon each with a unique artwork standard pattern. Each experimental stimulus had a matching grayscale shape used as catch stimulus. Examples of experimental and catch stimulus are presented in **Error! Reference source not found.**. The stimuli were split into two conditions, fluent or disfluent trials. Half the shapes were assigned to the fluent condition and the other half to the disfluent condition and this assignment was counterbalanced across participants. Both fluent and disfluent object motion are described in the section below.

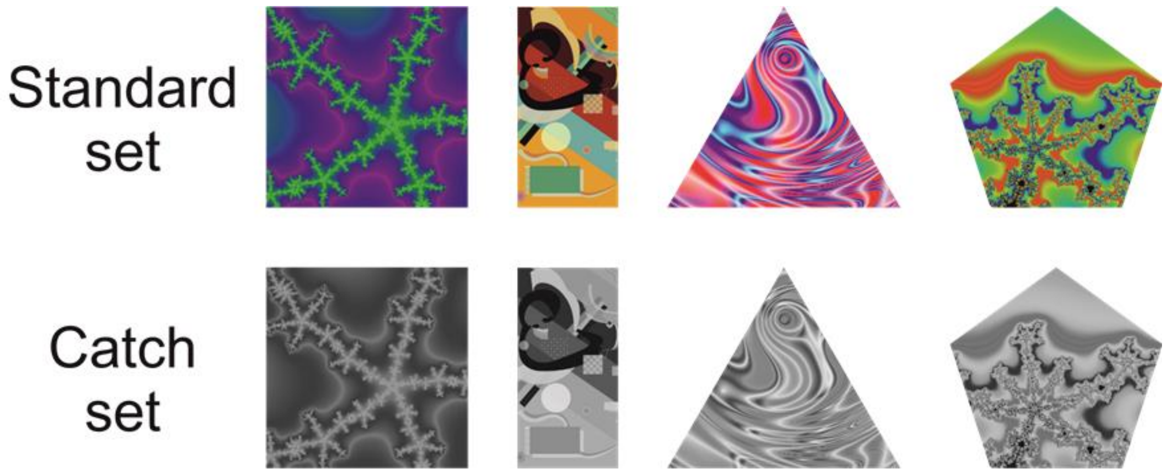


Figure 1. Stimuli, top layer is the standard set and bottom layer is the catch set

Object motion

During the trials where the object moved, it would appear in the centre of the screen and immediately begin to move for 2500ms at which point it would disappear. Objects either expanded or contracted and rotated either clockwise or counter-clockwise which resulted in four possible movements. Fluent movements had a constant rate of change of size and rotation (see top panel in Figure 2). Disfluent movements were generated by dividing fluent movement into 5 equal sections and then reordering them from [1-2-3-4-5] to [1-4-3-2-5] (see bottom panel in Figure 2).

At the moment of appearance, an expanding objects area was 900 mm^2 and for the contracting object the area was 14400 mm^2. The final area for all objects and rotations was 5625mm^2, similarly, the final orientation was the same for all objects. All objects rotated by 90° to the orientation shown in Figure 2.

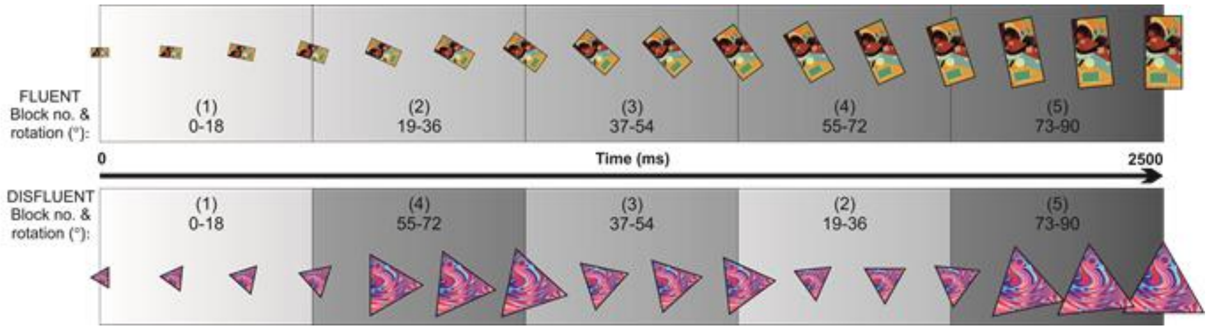


Figure 2. Illustration of the time course of the fluent and disfluent stimuli.

Experiment composition

The experiment consisted of a first rating block, a practice block, a task block, and a final rating block in that order. The composition of trials in the practice and task blocks were identical. The practice block was intended as a rehearsal for the task block. The rating block was identical in both the first and final ratings. All blocks are described below.

Rating block

In a rating block, participants would rate each standard object from the exposure block for liking. This method of object liking was used to assess the fluency effects. During the rating trial, an object would be presented and then participants would input a value using a 50cm long, 201-point Likert scale ranging from -100 to +100. Visually for the participants, the scale was a line with brackets at each end with no other demarcations. Participants were instructed to tap towards the left if they did not like the object, towards the right if they did like the object and the middle was a neutral area. Participants completed a rating block at the beginning and the end of each experiment.

Practice and task block

In both a practice and task block, participants carried out a ‘detection task’ to ensure participants were continually attending to the stimuli. The task required participants to press a button on the keyboard as soon as possible when they detected that the object had changed from its original colour to grey and the response window was 500ms. Trials where the object changed from colour to greyscale are referred to as ‘catch trials’ and trials where the object did not change are referred to as standard trials. During a catch trial, the object could change to its catch pattern in either block 2 or 4 of the rotation (See figure 3). Participants were not aware if a trial was standard or catch until the pattern changed.

Presentation order was randomised within each block. Participants were able to take a break between each block when there were instructions to call the experimenter back and explain the next step of the procedure and subsequently answer any questions about the upcoming block.

Response feedback

Response errors in the task were if the participant responded on a standard trial, did not respond during a catch trial or responding either before or after the 500ms response window on a catch trial. Response errors were followed by an error tone and a red screen border from the point of the error to 1500ms after the object had disappeared. Correct responses in the task were pressing within the 500ms window during a catch trial or not responding during a standard trial. Correct responses were followed by a green screen border for 1500ms after the object had disappeared.

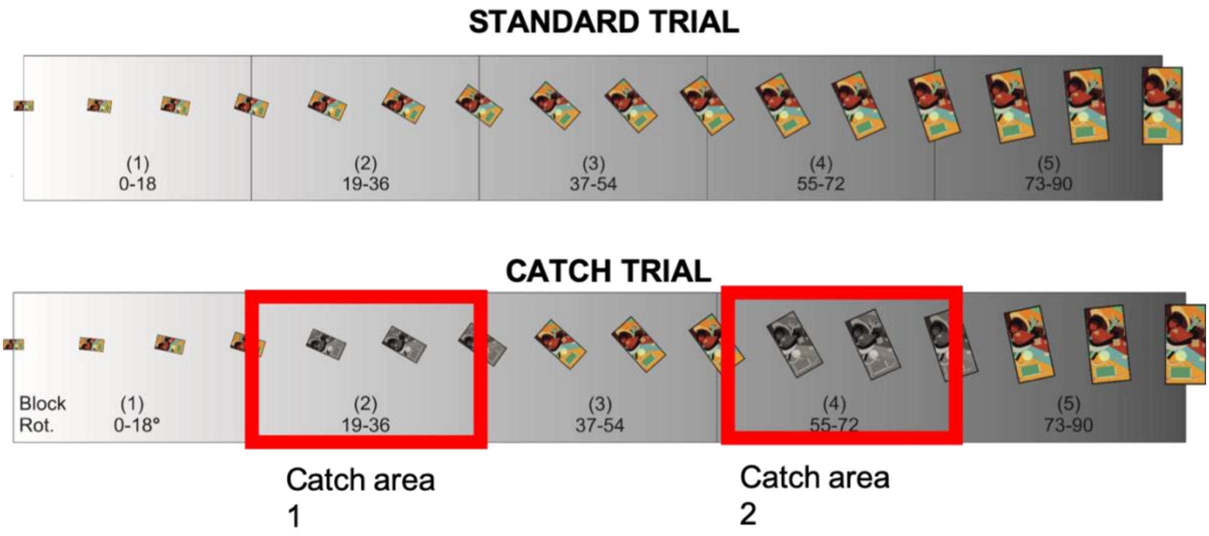


Figure 3. Illustration of the trials; standard trial on the top panel and catch trial on the bottom panel

Block composition

The practice block consisted of 4 trials; 2 standard and 2 catch, 2 of the shapes were fluent and 2 were disfluent. The stimuli were the same shape as the experimental stimulus but had different unique patterns. Participants received feedback on their performance and responses for the practice trials were discounted from analysis.

The task block, participants were exposed to each object 16 times (making a total of 64 trials). Of those exposures, 8 were catch trials and 8 were standard trials per object. Half of each trial expanded, and the other half contracted, half of each trials rotated clockwise and the other half counter-clockwise. Each object and trial type were exposed the same amount of times in each movement.

The rating blocks consisted of 4 standard trials, one for each object.

Determining power

Before data collection, a power analysis was conducted in RStudio (RStudio, Team, Boston, MA) to determine the appropriate number of participants to power the study. A planned two-way paired samples t-test using a Cohen's $d = 0.5$ with a target power = 0.8 returned a target number of 34 participants. This number was rounded up to 40 for each experiment in order to provide a robust investigation of fluency effects.

Data exclusion and analysis

Data were analysed using Matlab R2015a (The Mathworks Ink., Natick, USA). Participants who made an error on more than 25% of catch trials or 25% of standard trials were removed from the data set. An error would be pressing the button on a standard trial or pressing outside of the response window on a catch trial. Error rates are presented in the results section for each experiment.

Participants

All participants were students of the University of York who received either financial compensation or course credit for their participation. No participant completed more than one experiment and any participant data that was excluded from the experiment are provided within each experimental section. Exclusion criteria are also described in each experimental section. Protocols were approved by the University of York's Psychology Departmental Ethics Committee and were in line with the tenets of the Declaration of Helsinki. All participants gave written consent but were naive to the research purpose until the experiment was complete where they were debriefed and told the details of the experiment.

A total of 41 participants were tested. One participant exceeded the maximum error threshold for catch trials by failing to respond on 7 of 16 catch trials and was subsequently removed from the data set. None of the remaining participants made an error on more than 3 of 32 (mean ± SD = 0.2 ± 0.6) standard trials or more than 7 of 32 (mean ± SD = 2.4 ± 2.0) catch trials. The final sample consisted of 40 participants (3 male, M_{age} = 18.80, *s. d.* = .97).

Design

The design for analysing the experiment was a repeated methods 2x2 between subject ANOVA, analysing the effect of fluency (fluent or disfluent) and exposure (first and final) on preference ratings of objects.

Results and discussion

The means and confidence intervals for fluent and disfluent shapes after the first and final ratings are shown below in figure 4. Ratings were averaged across participants and conditions and these were analysed using a 2 factor (fluency x pre/post) repeated measures ANOVA. Results showed a main effect of fluency (F(1, 39), = 16.94, $p < .001$, $\eta p^2 = .303$), however there was no effect for pre-/post- exposure (F(1,39), = .91, $p = .345$, $\eta p^2 = .023$) and no interaction between fluency and pre-/post- exposure (F(1,39), = .30, $p = .589$, $\eta p^2 = .008$).

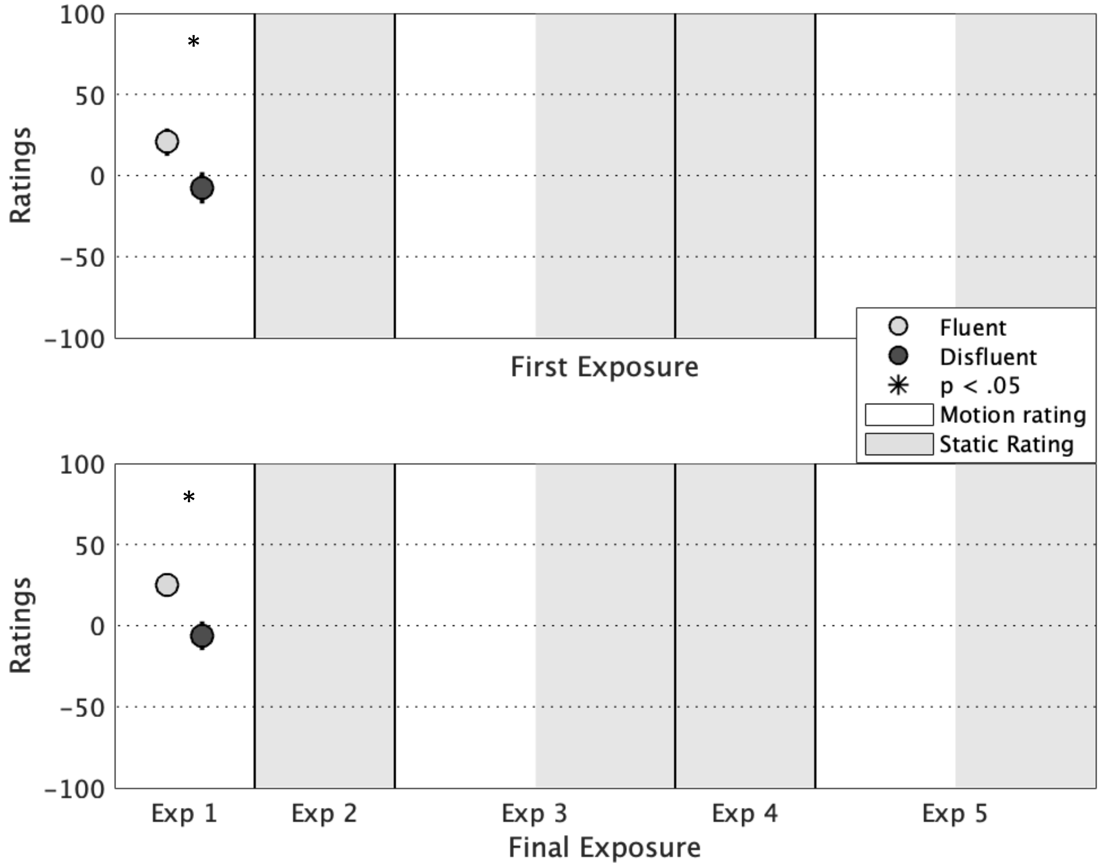


Figure 4. Means and confidence intervals for fluent (light grey) and disfluent (dark grey) participant ratings. First exposure top panel and final exposure on the bottom panel.

Two post-hoc paired samples t-tests were conducted between the fluent and disfluent ratings at first exposure and final exposure. The results showed a significantly greater preference for fluent movement in comparison to disfluent movement in both the first rating (t(39), = 3.43, p = .001 , d = .542) and the final rating (t(39), = 4.37, p<.001 , d = .691).

These results clearly confirm the hypothesis. Objects that move in a smooth and predictable manner are preferred to object's whose motion is disjointed and non-predictable. These motion fluency effects appear to be robust, being observed in the very first exposure to the stimuli. Furthermore, the lack of interaction between motion fluency and start/end of the experiment suggests that there is little learning, as the fluency preference effect does not get larger. However, the initial potency of the effect might have caused ceiling effects, where it is difficult to detect increases. This issue will be commented on further at later stages of this thesis.

Experiment 2

The first experiment showed a robust fluency effect derived from the new looming rotating motion. The aim of the second experiment in this chapter is to see if the fluency preference effect is present when the object is encountered in a different context. For example, after exposure to the object motion trials, the subsequent preference judgement is made when the objects are static. Whether there is learning of the object identity-motion relationship, and whether this can be detected when the object is assessed while stationary, is a critical issue for the generalisation and utility of these motion fluency effects.

Method

The methodology for Experiment 2 is a replication of Experiment 1 with the exception of the rating blocks. Instead of rating moving objects for preference, participants rated each object in its static picture form at the start and end of the experiment. I predict that there will be no difference in preference at the first rating as participants are not exposed to the motion-object associations, but there will be a preference for the fluent over the disfluent objects at the final rating. The size and orientation of the static image was the final size and orientation in each trial in the task block (see panel 5 in figure 2).

Participants

A total of 41 participants were tested. One participant exceeded the maximum error threshold for catch trials by failing to respond on 7 of 16 catch trials and was subsequently removed from the data set. None of the remaining participants made an error on more than 1 of 32 (mean ± SD = 0.2 ± 0.4) standard trials or more than 6 of 32 (mean ± SD = 2.4 ± 1.9) catch trials. The final sample consisted of 40 participants (2 males, mean ± SD = 18.80±.97).

Results and discussion

The means and confidence intervals for fluent and disfluent shapes after the first and final ratings are shown in figure 5. Ratings were averaged across participants and conditions and these were analysed using a 2 factor (fluency x first/final exposure) repeated measures ANOVA. Results showed no main effect of fluency (F(1, 39), = .356, p =.554 ηp^2 = .009), and no effect for first/final exposure (F(1,39), = 3.085, p = .087 , ηp^2 = .073). However, there was an interaction between fluency and first/final exposure(F(1,39), = 7.639, p = .010 , ηp^2 = .159).

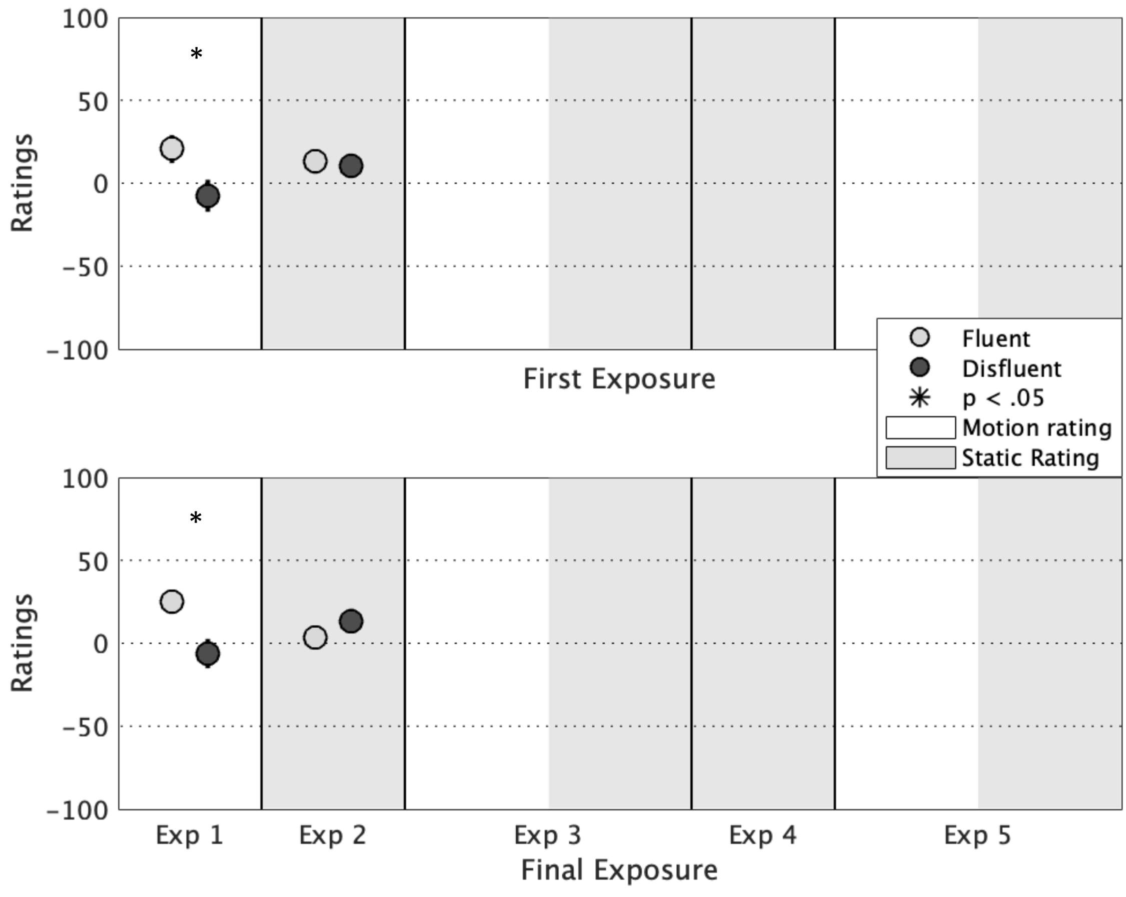


Figure 5. Means and confidence intervals for fluent (light grey) and disfluent (dark grey) participant ratings. First exposure top panel and final exposure on the bottom panel.

To break down the interaction and understand the results further, post-hoc paired samples t-tests were conducted. Results showed that there was no significant differences in ratings between fluent and disfluent objects at the first (t(39), = .429, p=.671, d = .068) or final (t(39), = -1.515, p=.138, d = -.239) exposures and there was no significant change in rating for the disfluent objects from the first to the final rating (t(39), = -1.055 p=.298, d = .101). Surprisingly, a significant change in rating was found for the fluent objects (t(39), = 3.055 p=.004 , d = .353) where the liking for fluent objects decreased at the final rating.

The significant interaction found was driven by a decline in liking for the fluent objects from the first to the final exposure. This is an unexpected finding and opposite to the hypothesised prediction. However, when looking at the data concerning my hypothesis, no memory effects or learned associations were shown. That is, in the final preference rating there was no evidence that objects that had previously moved fluently were preferred more than previously disfluently moving objects. Therefore, this experiment failed to show object association and memory effects: That is, even when objects are repeatedly observed moving in a fluent or disfluent manner, the evoked preference is not detected when the objects are no longer moving. With this in mind, it was necessary to replicate the experiment and attempt to extend the findings in a third experiment.

To this point, I have been testing motion fluency effects with preference assessment of moving (Experiment 1) and static objects (Experiment 2) in separate groups of participants. It is possible that a within participants design might be more sensitive than the between participants studies so far carried out. That is, it is possible that participants assessing both moving and static objects for preference within the same experiment could increase sensitivity to the association between an object's prior motion and its subsequent assessment when static (see Poulton (1982), for within participant influential companion effects). Therefore, this third experiment replicates the methodology of Experiments 1 and 2 by requiring the preference assessment of objects when either moving or static.

Experiment 3

This experiment aims to replicate Experiment 1 and 2 using a within subject design to see whether participants assessing both movement and static objects can increase sensitivity for the association between the movement and the static object.

Method

The methodology for Experiment 3 is a replication of Experiments 1 and 2 with an exception of the assignment of the objects (static or moving) in the rating blocks. In line with the previous two experiments, two objects moved fluently, and two objects moved disfluently during the exposure task. However, during the preference assessment trials at the start and end of the experiment, one pair of fluent and disfluent objects were rated while moving (replicating Experiment 1); while the other fluent/disfluent pair were rated when the objects were static (replicating Experiment 2). To counterbalance the stimuli appropriately, four versions of the experiment were run (see table 1).

Table 1. Experiment 3 versions and counterbalancing

version	**Square**	**Triangle**	**Rectangle**	**Pentagon**
1	fluent	fluent	disfluent	disfluent
	motion	static	motion	static
2	fluent	fluent	disfluent	disfluent
	static	motion	Static	motion
3	disfluent	disfluent	fluent	fluent
	motion	static	motion	static
4	disfluent	disfluent	fluent	fluent
	static	motion	static	motion

Participants

A total of 40 participants were tested (18 male, M_{age} = 20.65, *s. d.* = .1.48). None of the participants made an error on more than 2 of 24 (mean ± SD = 0.3 ± 0.6) standard trials or more than 5 of 16 (mean ± SD = 1.5 ± 1.4) catch trials.

Results and discussion

The means and confidence intervals for fluent and disfluent shapes after the first and final ratings are shown in figure 6. Ratings were analysed using a 3 factor (fluency x first/final exposure x static/motion rating) repeated measures ANOVA. Results showed a main effect of fluency (F(1, 39), = 9.143,p =.004 ηp^2 = .190), but no main effect for first/final exposure (F(1,39), = .129, p = .722 , ηp^2 = .003) or static/motion rating(F(1,39), = 2.363, p = .132 , ηp^2= .057). There was a significant interaction between fluency x static/motion rating (F(1,39), =8.303 p = .006, ηp^2 = .176) but no interaction between fluency x first final rating (F(1,39), = 2.056, p = .160 , ηp^2 = .050) or first/final rating x static/motion rating (F(1,39), = 3.342, p = .075, ηp^2 = .079) or fluency x first/final rating x static/motion rating (F(1,39), = 1.567, p = .218, ηp^2= .039).

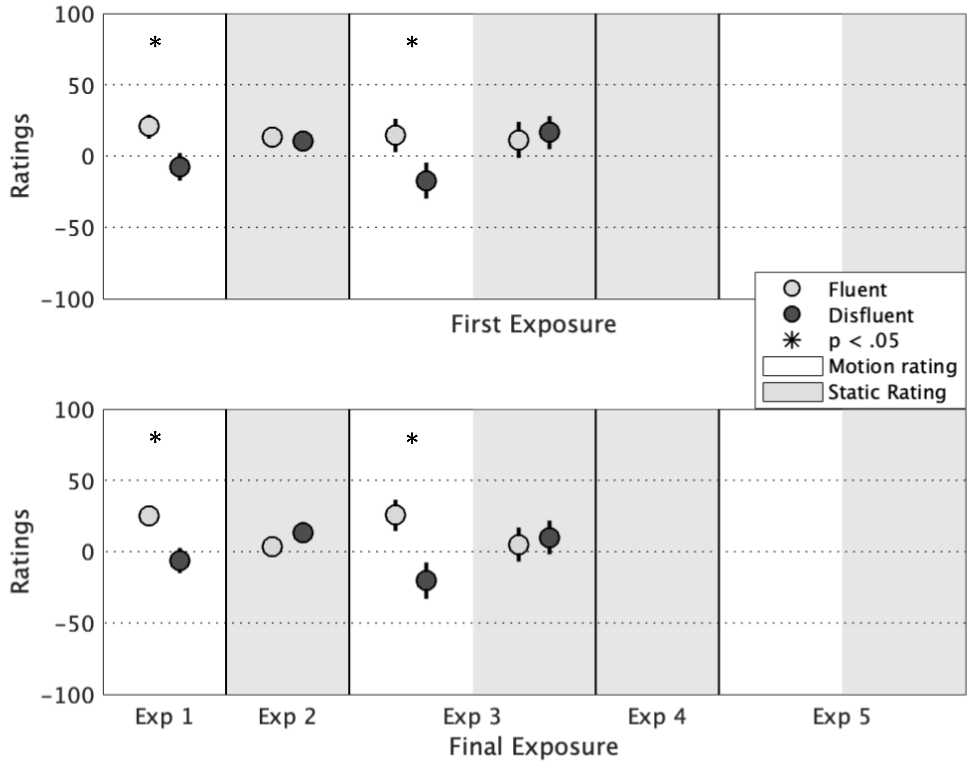


Figure 6. Means and confidence intervals for fluent (light grey) and disfluent (dark grey) participant ratings for Experiment 3. First exposure top panel and final exposure on the bottom panel. Light panel motion rating, darker panel static rating.

To interpret the significant interaction between fluency x static/motion rating, 2 x 2 repeated measures ANOVAs were conducted, one analysing the static ratings and one analysing the motion ratings. Replicating the results of Experiment 1, when participants were rating the object moving, the ANOVA results show a significant main effect of fluency ($F(1,39) = 17.842$, $p< .001$, eta^2= .314), however, similar to Experiment 1, there was no main effect for first/final exposure ($F(1,39) = .720$, p= .401, eta^2= .018). However, in contrast to Experiment 1, the interaction between the first/final exposure and fluency was significant ($F(1,39) = 4.505$, p= .040, eta^2= .104), where the preference effect was larger at the end of the experiment, suggesting that there is a role for learning in this object-motion association process.

To understand this interaction between fluency and exposure for ratings of moving objects, post-hoc t-tests were used to analyse the differences. Replicating experiment 1, there was a significant difference between fluent and disfluent ratings at the first ($t(39) = 3.473$ p= .001, d =.549) and final ($t(39) = 4.426$ p< .001, d =.700) exposure. Further analysis showed no change in ratings for the disfluent objects between first and final exposure ($t(39) = .500$ p= .620, d =.079) but a significant increase in liking for the fluent objects between the first and final exposure ($t(39) = -2.068$ p= .044, d =.-.330). This result shows that increased exposure resulted in a higher subjective liking of the fluent objects showing a possible effect of learning and memory retrieval for the fluent objects.

In contrast to the preference effects when observing moving objects, motion effects, also replicating the static object results of experiment 2, the analysis of the static ratings showed no main effect of fluency ($F(1,39) = .272$, p= .605, eta^2= .007), and no main effect of first/final exposure ($F(1,39) = 2.452$, p= .125, eta^2= .059) and finally no interaction between fluency and first/final exposure ($F(1,39) < 0.001$, p= .992, eta^2< .001).

This experiment affirms my findings of motion fluency associations: there are clear preference effects when assessing moving objects for liking but when the previously moving object is subsequently assessed while it is static no preference effects can be detected.

General discussion

The experiments in this chapter investigated three questions, (1) does motion fluency influence object liking? (2) are object-motion associations learned following repeated exposures? and (3) do object-motion associations transfer from moving to static presentations of objects?

First, in Experiments 1 and 3, I have demonstrated that liking of objects is influenced by the motion patterns that are associated with them. Objects that moved disfluently (with an unpredictable, disjointed motion) were liked less than objects that moved fluently (with a predictable, smooth motion). Second, there is some evidence that object-motion associations can be learned. In Experiment 3, liking ratings of the disfluent objects did not differ from the first to the final exposure, however, the liking ratings of the fluent objects increased from the first to the final exposure. This shows that the learned fluency effect was larger after repeated exposure for the fluent objects. This interaction was not seen in Experiment 1, so whilst associative learning of an object's identity with its motion fluency can be learned, effects might not always be detected with potent effects close to ceiling at initial viewing. Finally, there was no evidence to show that the association between an objects identity and the affect evoked by its motion transferred to situations where the object was no longer moving. That is, there was no difference between liking of fluent and disfluent associated objects in Experiment 2 and 3 after prior repeated exposures of the object's motion.

The prediction that learning of visuomotor properties would influence the object preference judgements, even with a context change (rating the object in a static form), was based on a literature that suggests that memory consists of visuomotor information from different modalities in distributed systems and when encountering an object at a later time, these visuomotor properties are retrieved (Barsalou, 2008). It was expected that learning would take place after multiple exposures to the objects motion and then when encountering the object again, this would lead to retrieval of the motion evoked affect. However, this was not the case.

The task in these experiments are a form of evaluative conditioning, whereby the neutral conditioned stimulus (CS, the object), when associated with a positive unconditioned stimulus (US, the fluent motion), takes on the positive properties and subsequently is liked more. Associations have been shown to develop following a small number of pairings and may go unnoticed by participants (Walsh & Kiviniemi, 2014). As typical of associative learning tasks, the participants were not explicitly told to learn the object-motion associations, but they had to carefully attend to the objects (the detection task) which may have facilitated learning. Furthermore, that the CS (object identity) and US (fluent/disfluent motion) were elements of the same object might also be assumed to facilitate the learning of the associations between the CS and the US. Although Experiment 3 showed some evidence for the associative learning as the liking effects were larger for the fluent objects after multiple exposures, this was not present in the other experiments.

There are two main issues that could explain these null results. The first issue could be the level of processing in the response task used. Currently, the response task is the same for all objects in the studies so far. That is, participants just had to detect a low-level luminance change in the object. It could be that the identity of the object was ignored and not encoded because after multiple exposures to each object, participants were just looking for the colour change. The second issue concerns the nature of the objects. The failure of retrieval from associative learning following context change may be due to the artificial stimuli (geometric shapes) which would not freely move in the environment. In associative learning, not all combinations of conditioned and unconditioned properties are effective, leading to boundaries on learning. Hence the nature of object identity has to be considered.

The experiments in this chapter have shown that perceptual fluency using motion has an effect in manipulating preference when the object is rated while moving. This was shown through the fluent objects being preferred over the disfluent objects. It has also found that when the object is rated while static, there is no retrieval of the fluency affect from memory. The experiments in the next chapter will address two limitations, levels of processing and object identity, in an attempt to overcome the associative learning barrier presented in this chapter.

Chapter 3: Motion fluency with deeper encoding

Introduction

The experiments in the previous chapter addressed whether object-fluency associations could be learned, and whether associations could be retrieved from memory when objects are later presented without motion. For example, does preference increase/decrease following repeated exposure to fluent/disfluent motion and is preference maintained in the absence of motion. Across three experiments, when an object was rated moving disfluently (with unpredictable motion and size changes) it was liked significantly less than when an object was rated moving fluently (with predictable motion and size changes). This affect was not seen when the object was subsequently rated while static, following repetitive exposure to the moving object. This failure to detect a memory trace for the fluency affects once the object is no longer paired with the motion shows an important boundary condition on perceptual fluency learning mechanisms, suggesting issues with the associative learning of the object-motion pairs.

Associative learning / evaluative conditioning (for a review see De Houwer, Thomas, & Baeyens, 2001) would predict that learning and retrieval would occur because the conditioned stimulus (CS) of object identity was repeatedly paired with the positive or negative unconditioned stimulus (±US) of motion fluency. However, the previous chapter found no evidence that the association could be retrieved when a motion cue was not present (Experiments 2 and 3). In other words, objects paired with fluent motion were preferred when assessed following a moving presentation but there was no difference in preference for the fluent or disfluent objects when assessed following a static presentation.

The failure of retrieval of associative learning following context change may be due to either the levels of processing determined by the response task or the stimuli used to examine object motion effects (geometric shapes), each issue will be discussed in turn.

First, the failure of retrieval could be attributed to the insufficient encoding of the object-motion pairs due to the task used in the experiment. When assessing an object for the colour change, participants had to press the same button for all four objects, which might result in the identity of each object being ignored. This could be because the detection of and the response to the object colour change is a low-level transient signal that potentially results in low levels of engagement, shallow encoding, and subsequently weaker memories formed (e.g. levels of processing theory, Craik & Lockhart, 1972). Whereas deeper, more complex encoding, in comparison to shallow encoding, improves learning and memory. For example, Moeser (1983) suggested that the more distinctive information encoded about a target resulted in a richer memory paths making the stimuli easier to retrieve from memory. Therefore, rather than a task relying on low-level perceptual judgments of grey-scale detection, if all objects were explicitly encoded as unique identifiable identities, then perhaps retrieval of the motion patterns associated with each identity would be more efficient.

Second, the stimuli employed in the previous experiment could impede learning as the objects were four unique geometric shapes, which would not freely move in the natural environment. In associative learning, not all combinations of stimulus properties can be effectively associated, leading to boundaries on learning. Indeed, animal studies indicate that associations may be learned more effectively when the stimulus and response are 'naturally' related and evolutionarily relevant. For example, in rats, the learned association between a flavour (the natural CS) and a subsequently received electric shock (an 'unnatural' -US) is limited to the environment in which the shock and flavour were encountered, meaning that that particular flavour is only avoided in the shock environment (i.e. association is context limited). However, when flavour is instead associated with an illness produced by poison (a 'natural' -US) the rat will avoid that flavour in all environments regardless of context. (See also Endo & Shiraki 2000; Garcia & Ervin, 1968; Garcia & Koelling ,1967; Green, Bouzas, & Rachlin ,1972; Green & Rachlin, 1973; Grote & Brown ,1971 for similar findings). With this in mind, the geometrical shape stimuli used in the previous experiments may be unsuitable for association with motion fluency because they do not 'naturally' move.

To address the two issues highlighted above, in an attempt to strengthen the associative learning of object identity with its pattern of motion following a context change, the experiments in this chapter employ two key changes. First, Experiment 4 changes the response task to require participants to explicitly identify each object. Second, Experiment 5 uses this new deeper encoding response task and objects that naturally move, that is, airborne winged insects. Using more realistic stimuli should increase the ecological validity of the object-motion pairing and facilitate associative learning. These changes should increase the likelihood of detecting fluency effects when those objects are subsequently presented statically.

Experiment 4

Experiment 4 is a replication of Experiment 2 (static object presentation for rating) with changes to the response key used in the task and practice blocks, the composition of the practice block and the object-condition assignments, each change will be explained in the methods section below. The new response task aims to bolster associative learning by requiring deeper encoding of each object's appearance whilst it is in motion. The task is to press one of two buttons determined by an object's identity when the presented object temporarily changes colour during its movement (two-alternative forced choice). In other words, participants must identify the target to retrieve the correct key assignment while observing it in motion. This means that object perception must pass preliminary stages concerned with low-level sensory information such as brightness and move to later stages which are concerned with pattern recognition and pairing input of object type against the learned associations of the object's motion (Craik, 2016). Such deeper levels of processing are more likely to result in a memory trace, so by targeting these we expect a richer and stronger memory trace associated with the objects.

In this experiment, participants will rate objects for liking before and after an exposure phase in which those objects are repeatedly and consistently paired with either fluent of disfluent motion. During ratings, each object is seen stationary to explore whether fluency effects strengthen following repeated exposure and, critically, whether fluency effects survive a change from a moving to static context.

Methods

Response task

In the previous 3 experiments, participants were required to press the space bar when the object changed from its standard colour pattern to its catch greyscale pattern. In this experiment, participants had to respond to the object's identity as well as the change in colour. They were required to press the left or right control key depending on the object presented (see Figure 7 for an example). The left control key was covered with a blue sticker and the right a green sticker (from here, the keys are referred to as the blue and green keys). Four versions of the experiment were run to counterbalance fluency and the key assignments for each object.

Practice block composition

The two-alternative forced choice task was much more cognitively demanding than the single key press from the previous three experiments. To guide the participants through the object-key assignments, three practice blocks were introduced. The first practice block included two objects assigned to the green key only and the second practice block included two objects assigned to the blue key only. The third practice block combined practice one and two and included both keys and all 4 objects. Every object in each practice trial featured one standard and one catch trial to produce 4 trials in practice block 1 and 2 and 8 trials in practice block 3. Each practice block started with verbal and written instructions for the upcoming trials and a reminder of the objects and key assignments. If participants made a key error during the trial, a reminder screen of key assignments would show (see error feedback).

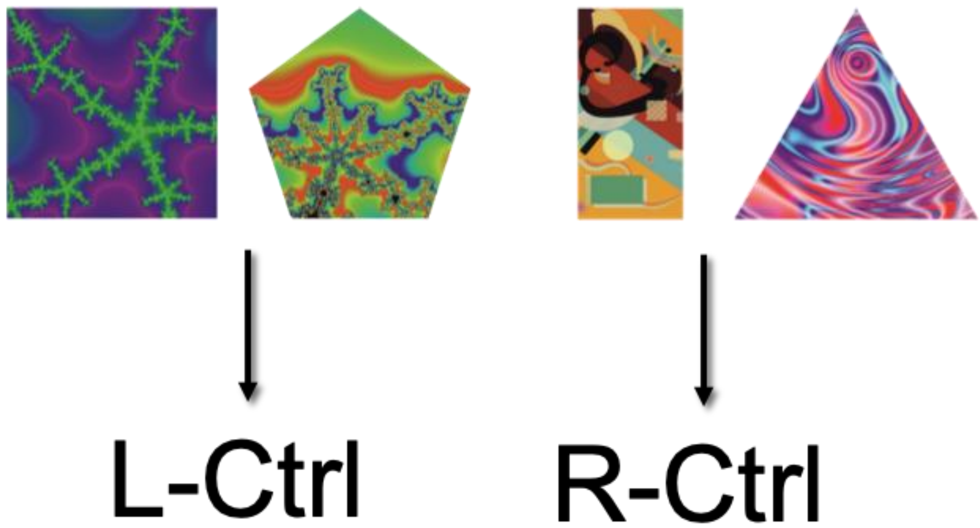


Figure 7. Object-button assignments for the task.

Error feedback

Correct responses in the detection task were pressing the appropriate key within the 500ms catch window on a catch trial, or not responding on a standard trial. If a correct response was made a green screen border would appear and remain until the end of the trial.

Incorrect responses could be responding on a standard trial, not responding on a catch trial, responding outside of the 500ms catch window on a catch trial, or by pressing the wrong key in the 500ms catch window (i.e. pressing the blue key when they should have pressed the green key for that object). If a participant responded, when they should not have, or pressed the wrong key then the object would immediately disappear, a 100ms error tone would play, and a red screen border would appear for 1500ms. If a participant failed to respond, then the object would complete its movement and disappear before a 100ms error tone would play, and a red screen border would appear for 1500ms. If participants erred by pressing the wrong key, then a reminder of the object-key assignment was shown after the error presentation.

Participants

Forty-two participants were tested. Two participants exceeded the error threshold for catch trials by failing to respond on 9 and 20 of the 32 catch trials. They were removed from the data set and none of the remaining participants erred on more than 1 of 32 (mean ± SD = 0.15±0.36) standard trials or on more than 8 of 32 (mean ± SD = 2.75±2.18) catch trials. The remaining sample consisted of 40 participants (13 males, age mean ± SD = 20. 26 ± 3.25, one participant did not disclose their age).

Results and discussion

The means and confidence intervals for fluent and disfluent shapes after the first and final ratings are shown in figure 8. Ratings were averaged across participants and conditions and these were analysed using a 2 factor (fluency x pre/post) repeated measures ANOVA. Results showed no effects of fluency (F(1, 39), = .075, p =.785, ηp^2= .002), or for pre-/post- exposure (F(1,39), = .953, p = .335 , ηp^2 = .024) and no interaction between fluency and pre-/post- exposure (F(1,39), = 1.696, p = .200 , ηp^2= .042).

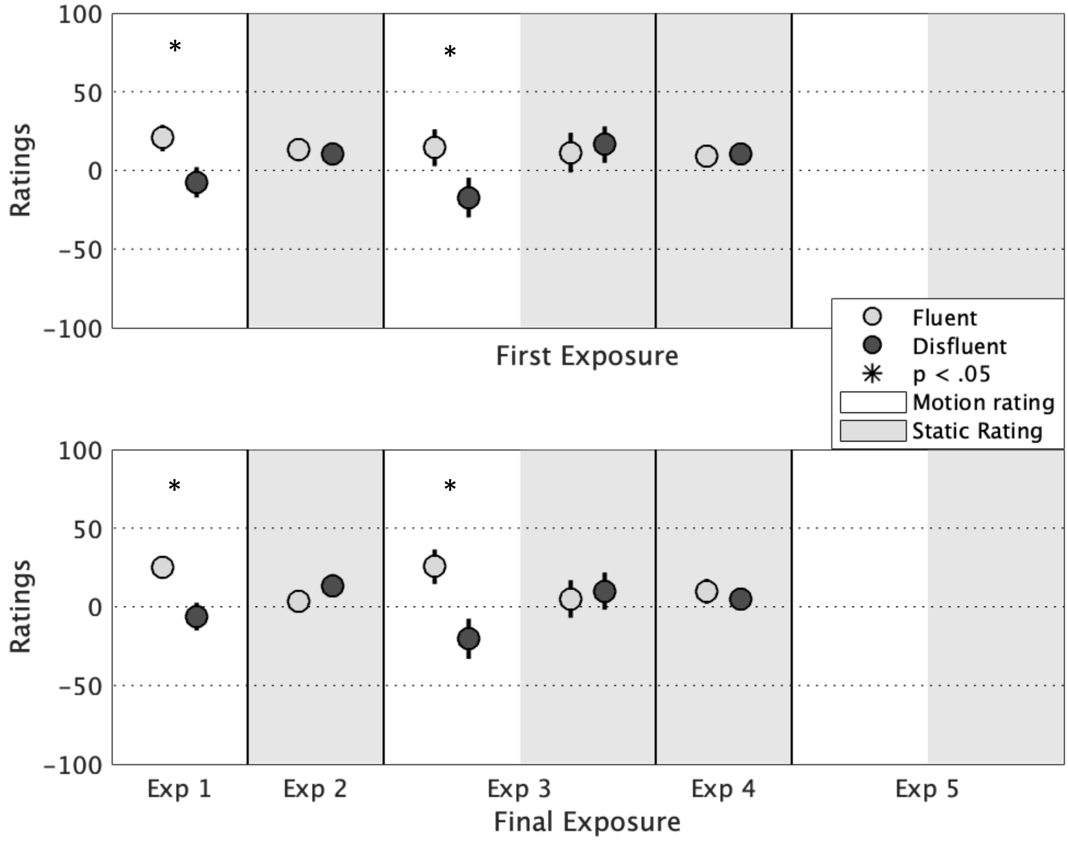


Figure 8. Mean (±95% confidence interval) for fluently moving (pale grey dots) and disfluently moving (dark grey dots) objects in Experiment 4.

This experiment has failed to detect a fluency affect again, when the objects are rated and viewed in their stationary form. This is a surprising result because the new task in this experiment encouraged a much deeper encoding process as participants had to focus attention on both the shape identity of the object and its motion pattern throughout the trial. The next experiment uses more realistic stimuli in an attempt to strengthen the object-motion associations.

Experiment 5

Experiment 5 is a replication of the design of Experiment 3 (assessment of both moving and static objects) combined with the deeper encoding two-key press task from Experiment 4, but now identifying objects that move in real-world environments.

Methods

Stimuli

Four winged insects featured in the experiment. Each insect had two forms: a full colour 'standard' form and a grey scale 'catch' form. At the moment of appearance, an expanding insect's wingspan was 35mm and a contracting insect's wingspan was 130mm. The final wingspan for all insects was 83mm. Similarly, the final orientation was the same for all insects (head towards top of screen as shown in Figure 9).

Figure 9. Full colour 'standard' (top row) and greyscale 'catch' (bottom row) forms of each insect.

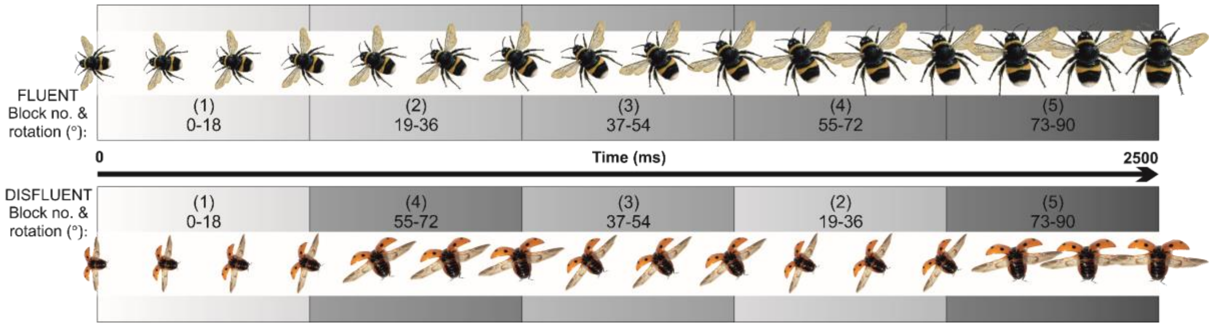


Figure 10. Schematic representations of object movements in the fluent (top panel) and disfluent (bottom panel) conditions. Note that the background colour in the experiments was a constant grey. In this figure the background varies to highlight the reordered sequence

Object-fluency assignment

Participants were assigned to one of four experiment versions, which determined the insect fluency and whether the insect would be rated following moving or stationary presentation. For every participant, two insects would be assigned to fluent motion and two to disfluent motion. One fluent and one disfluent insect would be rated while moving and the other rated while static. See Table 2 for insect motion assignments in each version.

Table 2. Motion assignments for each experimental version.

	Motion		**Static**	
Version	**Fluent**	**Disfluent**	**Fluent**	**Disfluent**
1	Bee	Dragonfly	Butterfly	Ladybird
2	Ladybird	Bee	Dragonfly	Butterfly
3	Butterfly	Ladybird	Bee	Dragonfly
4	Dragonfly	Butterfly	Ladybird	Bee

Participants

In an effort to maximise the robustness of the investigation, sample size was increased to 60 participants. Seventy-one participants were tested. Three participants were removed from the analysis because their first exposure rating exceeded +/-95 and a further 8 participants were removed for exceeding the error threshold (mean ± SD = 12.25 ± 3.92). This left 60 participants (22 male, 36 female, 2 undisclosed sex, age mean ± SD = 20.55 ± 0.80). None of the remaining participants erred on more than 7 of 32 catch trials (mean ± SD = 2.92 ± 2.10), or on more than 2 of 32 standard trials (mean ± SD = 0.34 ± 0.65).

Results and discussion

The means and confidence intervals for fluent and disfluent ratings are shown in figure 11. Ratings were analysed using a 3 factor (fluency; fluent or disfluent x rating type; static or motion x rating time; pre or post exposure) mixed methods ANOVA indicated that there were no effects of insect fluency (F(1, 59), = 1.50, p = .225, ηp^2 = .025), or first/final exposure (F(1, 59), = .31, p = .579, ηp^2 = .005), or motion/static rating (F(1, 59), = .05, p = .825, ηp^2 = .001). There was a significant interaction between insect fluency and first/final exposure (F(1, 59), = 7.39 p = .009, ηp^2 = .111), however, there was no interaction between insect fluency and motion/static rating (F(1, 59), = 3.19, p = .079, ηp^2 = .051), or first/final exposure and motion/static rating (F(1, 59), = 3.43, p = .069, ηp^2 = .055), or insect fluency and first/final exposure and motion/static rating (F(1, 59), = .03, p = .860, ηp^2 = .001).

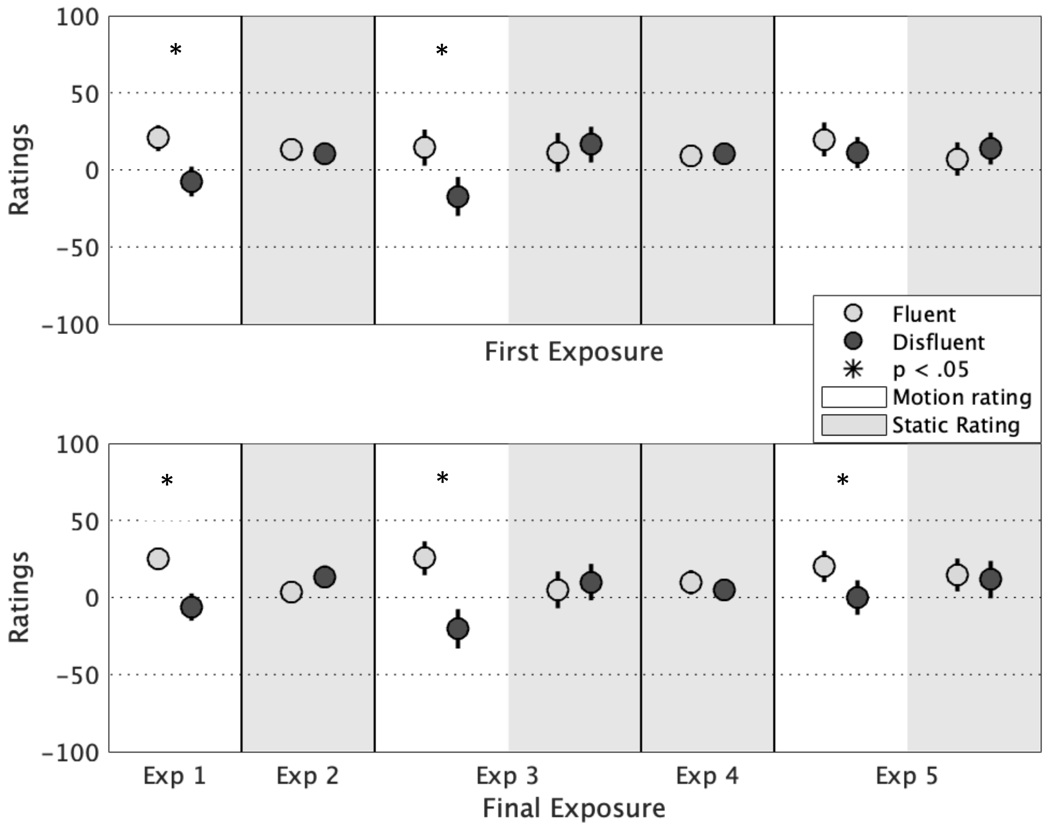


Figure 11. Mean (±95% confidence interval) for fluently moving (pale grey dots) and disfluently moving (dark grey dots) objects in Experiment 5. The white panel indicates ratings made after viewing moving objects and the grey panel indicates ratings after viewing

Further analysis examined the preference effects for the moving and static objects in separate 2 X 2 ANOVAs. Replicating the findings of Experiments 1 and 3, the results for liking assessments of moving objects indicated a significant main effect of fluency (*F*(1, 59), = 4.41, *p* = .040, ηp^2 = .070), however there was no main effect of first/final exposure (*F*(1, 59), = 2.78, *p* = .101, ηp^2 = .045) and no interaction between insect fluency and first/final exposure (*F*(1, 59), = 2.37, *p* = .129, ηp^2 = .039). In order to draw comparisons between these results and the results in the previous chapter, 2 one-tailed paired samples t-tests were conducted. Results showed that there was no difference between the fluent and disfluent insect ratings at the first exposure (*t*(59) = 1.13, *p* = .131, *d* = .146), however there was a significant difference between the fluent and disfluent insect ratings at the final exposure (*t*(59) = 2.49, *p* = .008, *d* = .22). This again suggests that there is some evidence for associative learning, where the effects of object motion fluency are stronger at the end of the experiment after repeated exposures.

A second 2 factor (fluency; fluent or disfluent x exposure; first/final) repeated measures ANOVA was conducted on the static ratings. Replicating the results of Experiments 1, 3 & 4, results indicated no effect of motion fluency (*F*(1, 59), = .08, *p* = ..775, ηp^2 = .001), there was no main effect of first/final exposure (*F*(1, 59), = .58, *p* = .444, ηp^2 = .010) and no interaction between insect fluency and first/final exposure (*F*(1, 59), = 3.32, *p* = .074, ηp^2 = .053).

Further analysis

Cross experiment analysis

Two additional analyses were performed on the combined final exposure ratings from the 3 experiments where moving was assessed (Experiment 1, 3, and 5) and from the 4 experiments where static objects were assessed (Experiment 2,3,4 and 5). These were 2-way repeated measures ANOVAs with a between subject factor of experiment and a within-subjects factor of fluency. These provided a high level of power (120 participants for the moving assessments and 160 participants for the static assessments) to assess the fluency effects following presentations of moving and static objects.

The analysis confirmed previous findings on fluency effects. Objects that moved fluently were preferred over objects that moved disfluently when ratings followed a moving presentation (F (1,117), = 33.56, p <.001, ηp^2 = .223), there was no main effect of experiment (Expts. 1,3,5) (F(2,117), = .80, p =.451, ηp^2 = .014) and no interaction between fluency and experiment number (1,3,5) (F(2,117), = 1.60, p =.206, ηp^2 = .027).

Confirming our previous analysis, the motion fluency effect on object preference was not seen when static objects were rated for preference. That is, there was no significant difference between fluent and disfluent ratings (F (1,156), = 0.01, p =.914, ηp^2 <.001), no main effect of experiment (2,3,4,5) (F(3,156), = .07, p =.978, ηp^2 = .001), and no interaction between fluency and experiment (2,3,4,5) (F(3,156), = 1.01, p =.391, ηp^2 = .019). This substantial increase in power provides further evidence for the null effect: preference does not transfer from moving to static objects in this paradigm.

General discussion

Experiments 4 and 5 revisited three questions from the previous chapter: a) does motion fluency affect object liking?; b) can object-motion associations be learned and influence object liking?; and c) do any such associations still affect object liking when the object is stationary (i.e. a different context)? These questions were further examined with key changes in the experimental design – the two-alternative forced choice task that encourages deeper encoding and a change of stimuli from geometric shapes to common airborne winged insects.

For the experiments in the previous chapter, the lack of fluency effects for statically presented objects may have been due to limitations of associative learning context. That is, not all combinations of stimulus properties can be effectively associated (Garcia, Kovner, & Green, 1970) and greater 'naturalness' in the scene may facilitate associative learning between an object's identity and its pattern of motion. With this in mind, the stimuli were changed from naturally stationary objects to winged insects, which possess the ability to move freely and, in a way, were reminiscent of the designed motion. This increase of ecological validity should facilitate associative learning of object-motion pairings. Furthermore, the replacement of the single key task in the previous experiments with the forced choice task here was to encourage deeper encoding of the object identity. Now, in order to respond correctly, participants were required to rapidly identify the insects then retrieve the correct key assignment before any response to the catch colour change could occur. With these changes we hoped to increase the likelihood of detecting fluency effects when objects are presented statically. However, as was the case in the previous experiments, fluently moving objects were preferred over disfluently moving objects but only when objects were assessed following movement (i.e. not when assessed following a static presentation).

Although the motion fluency effect was replicated for moving objects, the preference for the fluent over disfluent objects at the first rating in Experiment 1 and 3 was absent from Experiment 5. It is possible that the insects were more emotive stimuli and participants could have had prior expectations and experiences with the insects. After repeated exposure however, there was a significant preference for the fluent over the disfluent moving insect. The emergence of the fluency effect at the end of the experiment provides some evidence for associative learning after prior exposures.

The absence of fluency affects for the static ratings in Experiments 2 and 3 was replicated in Experiments 4 and 5. When objects were rated following a static presentation, participants' liking ratings were unaffected by previously seen object-motion pairings. Although this was also the case in the previous chapter, it was expected that changing the response task to encourage deeper encoding of the object-motion pairings and increasing the ecological validity of stimuli would enrich associative learning and lead to preference for fluent objects following repeated exposure to object-motion pairings. The results, however, demonstrate that any learning of object-motion association indicated by the motion rating condition were either undetectable or irretrievable from memory following a change in context from motion presentation to static presentation.

In summary, in these final two motion experiments of the thesis, I demonstrate that retrieval of priori associations between an object's identity and its pattern of motion does not transfer to new contexts where motion is no longer observed (see also Endo & Shiraki, 2000; Garcia & Ervin, 1968; Garcia & Koelling, 1967; Green et al., 1972; Green & Rachlin, 1973; Grote & Brown, 1971). Certainly, in terms of these basic perceptual processes such as motion, associative learning appears limited and to be context dependent. This is in contrast to the well-established phenomenon of evaluative conditioning that mediates the effects of advertising (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010).

The limited associative learning observed in the current experiments has practical implications for visuomotor fluency used as a behavioural change technique. Though it is possible to bias preference in the moment when participants see an object move, it is critical that the preferences are robust enough to survive a context change to meaningfully impact behaviour. For example, the fact that the motion fluency preference effect vanishes following a small change of context suggests that any learned preference is extremely unlikely to transfer to the real world. Overcoming this boundary of context change appears to be a major challenge if 'real-world' preference change is to be achieved via manipulations of basic visuomotor processes.

Across a series of 5 experiments, I have demonstrated this important boundary condition of associative learning and retrieval from memory for object-motion pairs. In an attempt to strengthen these associations, I have tested both a within-subject and between subject design, utilised a new task that encourages active engagement of the object-motion pairs, increased the sample size and finally moved towards more ecologically valid stimuli. These experiments have shown that there is a robust fluency effect when objects are rated while moving, however, there appears to be fragile memory effect.

Due to the failures of associative learning and limited likelihood of broader real-world effects from the techniques described thus far, the experiments in the next chapter test two new techniques for behavioural change: perception and inhibition. These experiments also begin to address the key thesis aim of combining multiple techniques to see if this creates a greater preference affect than each technique in isolation.

Chapter 4: Perception and Inhibition

Introduction

In the previous two chapters, I have created a technique, using motion, to manipulate perceptual fluency which can influence object preference. That is, when an object moved disfluently (with unpredictable motion and size changes) it was liked less than objects that moved fluently (with predictable motion and size changes). The preference for fluently moving objects was observed when liking assessments were made on *moving* objects but, critically, not observed when assessments were made on *static* objects (Flavell, McKean, et al., 2019). This failure to detect any learning and memory of prior perceptual fluency for static objects is an important boundary condition and this impacts on the overall thesis aim of developing a behavioural change game to manipulate preference. If there are no memory traces, then motion has limited benefit as the preference effect will not transfer into other contexts. In the perceptual fluency literature, there is little evidence for longer-term, stable effects in preference change after the manipulation has ended as the preference is typically measured on a trial-by-trial basis for in the moment liking (e.g., Reber et al., 1998; Winkielman et al., 2003). Therefore, it was necessary to develop a new experimental approach that may facilitate the transfer of fluency effects from displays where there is a perceptual manipulation, to assessment displays where there is not. The experiments in this chapter describe such an approach using three methods; perceptual fluency, motor-action fluency and inhibition.

There is an established literature that uses perceptual fluency techniques to manipulate preference, one of these is stimulus presentation time. That is, when an object or stimuli is viewed for longer, it becomes more familiar and is preferred over stimuli that are viewed for less time (e.g., Forster et al., 2015; Forster et al., 2012; Flavel et al., 2018). For example, previous research by Reber, et al., (1998) has demonstrated that as stimuli were presented at increasing intervals from 100ms to 400ms, the subjective liking of the stimuli increased. The assumption was that longer viewing time improved processing fluency, which was misattributed as liking. Interestingly, when using physiological measures, there is a relationship between presentation time and positive affect. Winkielman and Cacioppo (2001) found that a longer presentation time induced more Zygomaticus activity and higher self-report liking ratings, indicating a greater pleasure experience. These studies provide evidence for robust preference manipulation experienced in the moment. There is little known about the longevity of this effect and whether the preference can be retrieved when the stimuli no longer possess different temporal properties.

Alongside perceptual fluency, some experiments in this chapter will also manipulate motor-action fluency. How an individual interacts with an object can shape their preference (Carr, Rotteveel, & Winkielman, 2016). There is evidence in the literature for positive emotion associated with action, research has found that the ease of self-directed or observed action can increase preference for the encountered objects. For example, when participants self-produced an action of grabbing/moving an unobstructed (fluent) or obstructed (non-fluent) object, the objects associated with the fluent actions were preferred. This pattern was also seen when participants merely observed someone completing the actions rather than directly interacting with the object themselves (Hayes et al., 2008). Similarly, research using electromyography found that greater sensorimotor fluency in a compatible/incompatible sorting task induced a greater positive physiological response for fluent, compatible objects in comparison to incompatible, not-fluent objects, shown through increased zygomaticus major activity when producing fluent actions (Cannon, Hayes, & Tipper, 2010). Similarly, Beilock & Holt, (2007) asked typists to rate two letter dyads for liking, one dyad required same finger typing and the other required dual finger typing. Results showed that skilled typists preferred dual finger typing, even when they could not explain how the dyads differed. It is argued that the former dyad would evoke competition/interference, creating disfluency. These effects are seen even when observing letters on a screen with no action required, this demonstrated that previous actions were retrieved from memory. This research shows retrieval effects which suggest that including action processes in games could be an effective way of changing behaviour.

Finally, the last preference manipulation used is inhibition, more specifically, stop-signal inhibition. In stop-signal inhibition, a signal is intermittently paired with the presentation of a stimulus as a sign for the participant to withhold or cancel a response (Verbruggen & Logan, 2008). Previous research has found that cancelling or withholding a response in the presence of a stop-signal implicitly devalues the stimuli (e.g., Wessel, O'Doherty, Berkebile, Linderman, & Aron, 2014). Studies have also found similar results with faces. For example, a face paired with a stop-signal was devalued and deemed less trustworthy than faces paired with a response (Fenske et al., 2005). The negative affect produced by the stop-signal task is retrieved from memory when encountering the stimulus later (for example, after the study when no longer actively inhibiting the stimulus). This has been consistently shown in food preference studies, where consumption of the inhibited stimulus is reduced and implicitly devalued and this effect is sustained over time (Houben & Jansen, 2011, 2015; Lawrence, O'Sullivan, et al., 2015; Nederkoorn et al., 2010; Veling et al., 2011, 2013). For this reason, the inhibition technique is employed in real-world settings to reduce food intake in dieters (Veling et al., 2011) and reducing alcohol consumption in at-risk drinkers (Houben et al., 2012). This sustained effect is a crucial element to the experiments in this chapter, as my previous preference shift experiments have failed to produce a memory trace.

The experiments in this chapter investigate both perceptual fluency and inhibition in essentially the same experiment, which enables an initial examination of the two processes. Furthermore, I examine whether preference can be shifted in a very short 3-minute game-like task. As far as I am are aware, this is a significantly shorter procedure than previously employed, where in some cases the task/game is engaged with over weeks (e.g., Veling et al., 2014). If effects can be detected in such a short period of time, then this bodes well for such techniques in games where repeated returns are the norm, where spaced learning has been shown to result in more robust learning and retrieval (e.g., Bakkour et al., 2018).

This approach enables a further investigation of a potentially important issue. So far research tends to focus on one approach, such as studies examining a particular inhibition approach such as stop-signal, or perceptual fluency approaches such as the effect of contrast or symmetry. Of course, when utilizing techniques in a game setting where players interact with characters to achieve goals over multiple levels and repeated playing episodes, a wide range of techniques could be integrated. For example, to reduce preference for unhealthy foods, inhibiting action towards those stimuli on some trials could be merged with various perceptual disfluency techniques on other trials. Embedding in a game the wide range of established perceptual fluency and inhibition techniques could result in deeper encoding and more stable longer-term effects that generalize beyond the game. Of particular note, I currently have no knowledge of how combining techniques, such as inhibition and perceptual fluency, within a particular moment of experience effects the stability of preference change. I intend to explore this issue for the first time in the current series of simple short game-like tasks.

The following goals will be pursued. First, Experiment 6 will examine pure perceptual and inhibition effects in a new key-press procedure, to examine their effects on preference change. Then Experiment 7 will begin to combine techniques. One goal will be to introduce motor-action fluency, where participants have to directly reach for targets on a touch screen rather than merely pressing a computer key. I predict that combining perceptual and motor-action fluency will increase preference change effects. Then Experiment 8 will engage with the second goal, which will be to combine perceptual fluency, motor-action fluency and inhibition in to one task, to examine whether this further increase preference effects.

Experiment 6

The task is game-like, in that participants are required to 'catch' rapidly disappearing food items (grapes) by pressing the spacebar to stop them disappearing. This study directly examines two manipulations in a between-subjects fashion: a perceptual fluency condition (as stimulus presentation rate) and an inhibition condition (as stop-signal task, e.g., Houben, 2011).

It is important to note that these are initial exploratory experiments. Unlike the work of Lawrence et al (2019) and van Koningsbruggen et al (2014) for example, at this stage I am not attempting to tackle real-world issues, such as shifting preference from unhealthy foods (e.g., pizza, crisps, chocolate) towards healthier fruit and vegetables. Although that is a critical long-term goal, these initial basic experiments investigate shifts between similar stimuli in the same category. This less demanding preference change would seem to be the appropriate initial approach to examine whether preference can indeed be changed with a very short task lasting just 3 minutes, and to initially directly investigate perceptual-fluency, inhibition and the combination of these techniques.

In this task, participants viewed 10 objects which appear on the screen simultaneously. In each trial, the objects were either all grapes or leaves and they would quickly disappear one at a time. There were red and green colours of both grapes and leaves, though only one colour would be used in any given trial. The participants' task was to 1) respond to grapes as quickly as possible by pressing a button to halt the object disappearance, and 2) not respond to any leaves (i.e. not press the button). Participants experienced either a perception or an inhibition condition. In the perception condition, one colour of grape (the fluent grape) would disappear more slowly than the other colour of grape (the disfluent grape). The more slowly disappearing grape has greater fluency due to longer viewing time (Reber et al., 1998). In the inhibition condition, both colours of grapes disappeared at the same rate, but participants had the extra instruction of withholding a response (i.e. not pressing the button) if a ‘yucky’ face (the stop-signal) appeared at any point during the trial. This stop-signal appeared for half of the trials of one colour of grape (the disfluent grape) and never for the other colour of grape (the fluent grape). Based on previous literature for perception and inhibition, I predict that preference will be higher for the fluent over the disfluent grapes across both the perception and inhibition conditions.

Methods

Apparatus

Participants sat at a table in a lit room facing a 23" touch screen monitor (HannsG (Taipei, Taiwan) HT231HPB, 1920×1080 pixels). A keyboard was positioned on the table between the participant and the screen approximately 30 cm away. Participants and the keyboard spacebar were positioned at the screen's horizontal centre. Stimulus presentation (60Hz) and response recording were achieved using custom scripts and Psychtoolbox 3.0.11 (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997) operating within Matlab 2018a (The MathWorks Inc., Natick, USA) on a PC (Dell (Round Rock, USA) XPS, Intel (R) Core (TM) i5-4430, 3 GHz CPU, 12 GB RAM, 64 bit Windows 7).

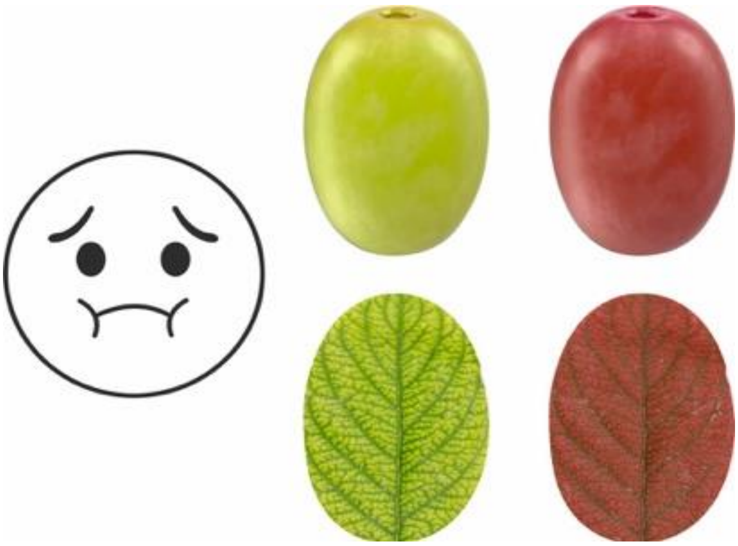


Figure 12. Stimuli used in all conditions

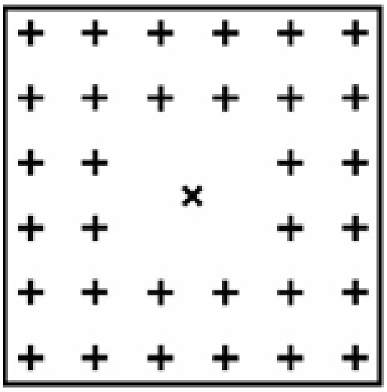


Figure 13 Schematic representation of where the 10 targets can appear in on the screen.

Stimuli

The red grape was a re-coloured version of the green grape. A single leaf was re-coloured to closely match the two grape colours. Leaf outlines were edited to match the profiles of the grapes. Edits made with CorelDraw 2018 v20 (Corel Corporation, Ottawa, Canada).

Experiment composition

The experiment consisted of a practice block, a task block, and a rating block in that order. Participants were assigned to either a perception or inhibition condition. The practice and task blocks differed between conditions, but the rating block was always the same. Fluency was manipulated using presentation time (fast / slow) in the perception condition and stop-signal association (present / absent) in the inhibition condition. This led to a 2x2 between-within design.

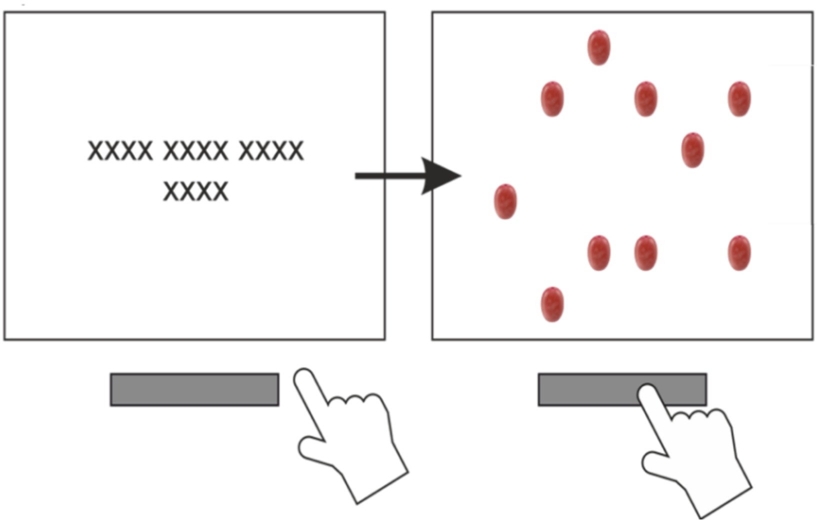


Figure 14. Experiment 6 response task. Participants press space bar if grapes appear. The left panel shows the screen at trial start and the right panel shows the participant pressing the space bar in the presence of grapes.

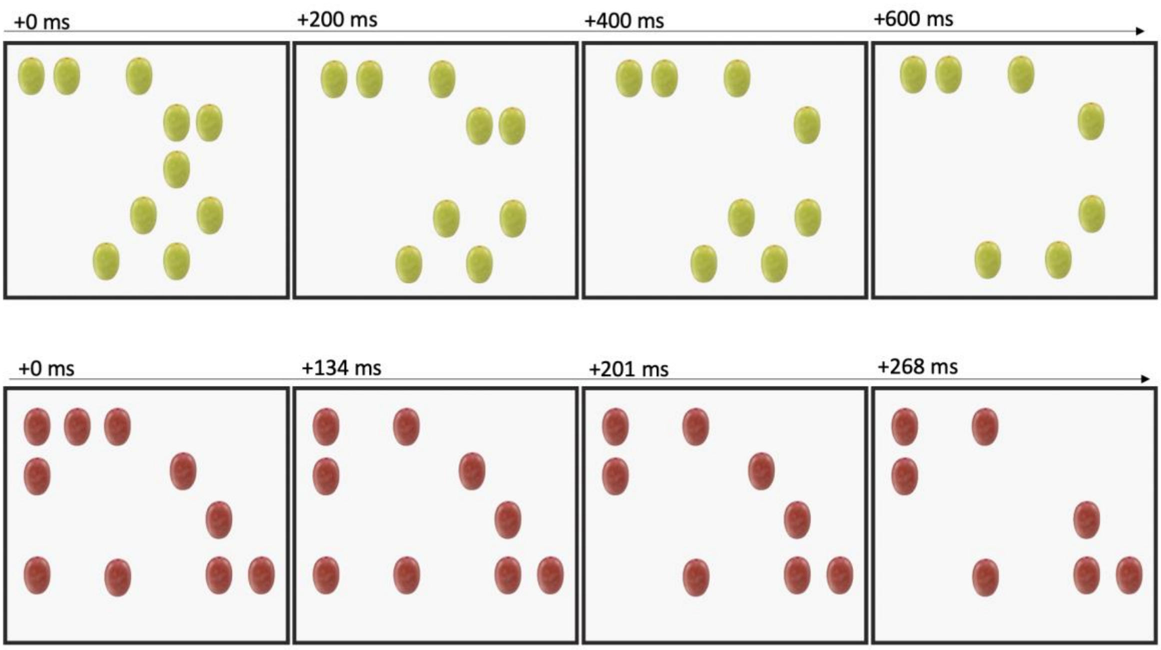


Figure 15 Schematic representation of perception condition. Top: a fluent trial where a grape disappears every 200 m. Bottom: disfluent fast grape trial where a grape disappears every 67ms. Note that the square black border was not shown during the experiment and is here for illustration only.

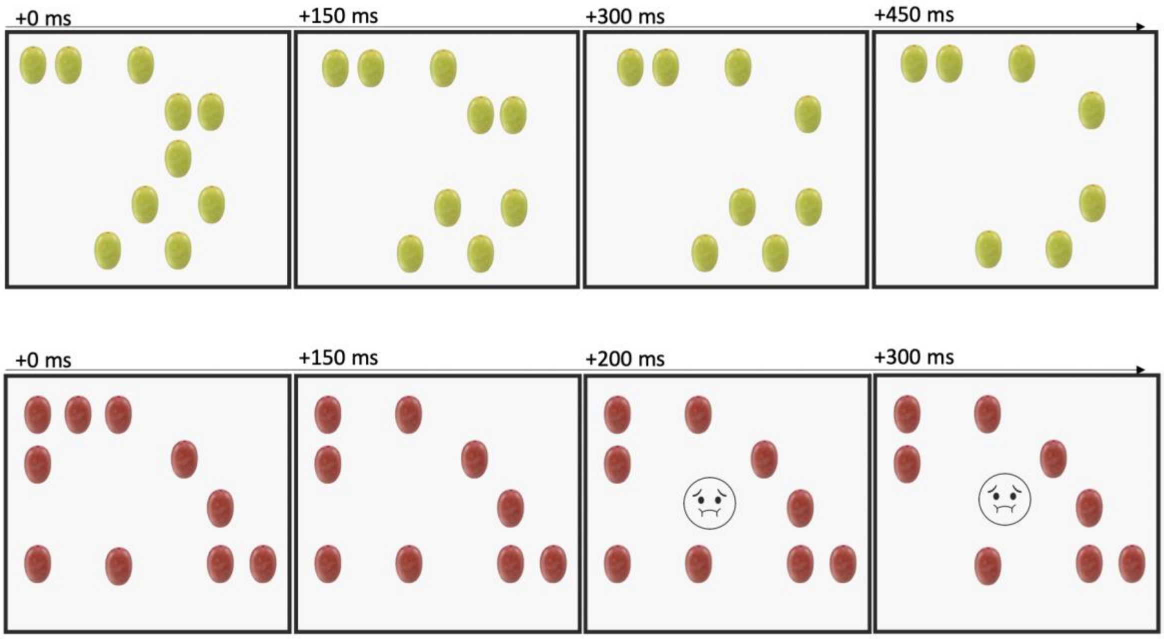


Figure 16 Schematic representation of inhibition condition trials. Bottom: an inhibition trial where a grape disappears every 150ms and the 'yucky face' appears 50ms after the first grape disappearance. Top: a go trial. Note that the square black border was not shown during the experiment and is drawn here for illustration only.

Perception condition trials

At the start of a trial a fixation cross appeared. Then 10 objects appeared on the screen simultaneously. The objects were either all green grapes, all red grapes, all green leaves, or all red leaves, (see Figure 15). Each object was randomly located on a grid (see Figure 13). The objects would then disappear one at a time.

Participants were instructed that if grapes appeared then they should press the space bar as quickly as possible (Figure 14), but if leaves appeared, they refrain from pressing the space bar. This discrimination of grape from leaf was to ensure that participants actively engaged with identifying the presented objects to facilitate encoding of those objects. This intention was the same in the inhibition condition. A grape trial ended when either the space bar was pressed or when all of the objects had disappeared.

Pressing the space bar for the grape trials or not pressing the spacebar for leaves resulted in successful trials. Failing to press the space bar on a grape trial or pressing the spacebar on a leaf trial resulted in an unsuccessful trial. After a successful trials the next trial would begin immediately, whereas after an unsuccessful trial an error tone would play and all on-screen objects would be replaced by feedback reading either “OH NO, you shouldn’t have saved the leaves” or “OH NO, you didn’t save any grapes”, as appropriate.

One colour of grape would disappear faster than the other (counterbalanced between participants). The fluent (slow disappearing) grapes disappeared at a rate of one every 200ms and the disfluent (fast disappearing) grapes disappeared at a rate of one every 67ms. Both colours of leaf disappeared at a rate of one every 150ms. Participants were not told of the differences in disappearance rates.

This discrimination of grape from leaf was to ensure that participants actively engaged with identifying the presented objects to facilitate encoding of those objects. This intention was the same in the inhibition condition.

Inhibition condition trials

These trials were exactly the same as the perception condition except for two changes: the inclusion of a stop-signal and the rate of object disappearance.

In addition to the perception instructions, participants were told to not respond if a yucky face (the stop-signal, see Figure 16) appeared during a trial. The face could only appear in the centre of the screen (see Figure 13) and would remain until the trial ended. If they responded when a yucky face appeared, an error tone would play and all on-screen objects would be replaced by feedback reading “OH NO, you pressed at a yucky face”. The face would only ever appear for one colour of grape (red or green, counterbalanced across participants, see condition assignments) and would never appear on leaf trials. The face would appear on 50% of the assigned grape’s trials.

All grapes disappeared at a rate of one every 150ms and the yucky face appeared 50ms after the first grape disappeared (i.e. 200ms after the grapes appeared). The leaves also disappeared at a rate of one every 150ms.

Rating trials

A single red or green grape would be presented in the screen centre with instructions to rate it between 1 (dislike) and 9 (like) using the keyboard’s number pad. The other colour of grape would then be presented for liking rating.

Block composition

In both conditions: the practice block consisted of 4 grape trials and 2 leaf trials; the task block consisted of 32 grape trials and 16 leaf trials; and rating block consisted of 2 grape trials. In each block half of grape trials were fluent and half were disfluent, and half of leaf trials were green, and half were red. Trial order was randomised within blocks between participants. The experiment was self-paced after verbal instruction by the experimenter at the start of the experiment.

Data exclusion and analysis

Participants were excluded if they responded on >25% of leaf trials in the task block. The task took ~3 minutes to complete.

Participants

All participants were recruited from the University of York's Department of Psychology participant recruitment system. Participants received either course credit (Department of Psychology students only) or financial compensation for participation. No participant completed more than one experiment. Participation numbers are provided in each experimental section. Exclusion criteria are described in Data Exclusion and Analysis. Protocols were approved by the University of York's Psychology Departmental Ethics Committee and were in accord with the tenets of the Declaration of Helsinki. Participants gave written consent but were naïve to the purpose of the research until participation was complete.

In the perception condition, 42 participants were tested, 2 participants were removed due to being over the error threshold, leaving a final sample of 40 participants (6 males, 31 female, 3 undisclosed, age mean ± SD = 19.58±2.46). No participants responded on more than 3 of 16 leaf trials (mean ± SD = 1.65 ± 1). In the inhibition condition, 40 participants were tested (5 males, 35 females, age mean ± SD = 19.33±1.59) and none responded on more than 4 of 16 leaf trials (mean ± SD = .63 ± .98).

Results and discussion

A mixed method 2 (fluent and disfluent) x 2 (perception and inhibition) ANOVA was conducted on the ratings (See figure 17). Results showed a main effect of fluency ($F(1,78) = 9.96$, $p = .002$, $\eta p^2 = .113$). There was no main effect of inhibition/perception condition ($F(1,78) = 1.65$, $p = 1.00$, $\eta p^2 < .001$) and no interaction between fluency and inhibition/perception condition ($F(1,78) = .52$, $p = .473$, $\eta p^2 = .007$). The main effect of fluency and no interaction show that fluent grapes were preferred over disfluent grapes and there was no difference in preference for the perception or inhibition condition.

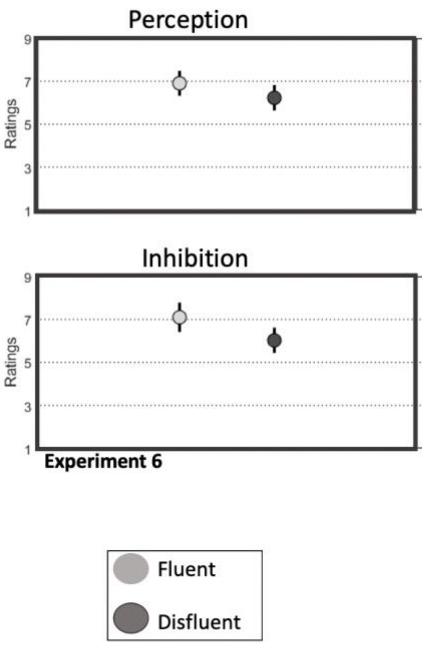


Figure 17. Means and 95% confidence intervals for the preference ratings for Experiment 7, for the fluent (light grey) and disfluent grapes (dark grey). Perception condition is the top panel and inhibition is the bottom panel.

The aim of this experiment was to see if a short 3-minute game using perceptual fluency and inhibition could manipulate preference and it was hypothesised that the fluent grapes would be preferred across both conditions. In the perception task, the fluent grapes that stayed on the screen for longer were preferred over the disfluent grapes that disappeared quicker. In the inhibition task, grapes paired with a go response were preferred over grapes paired with an intermittent go and an intermittent stop signal. These results show that my short 3-minute game was successful in manipulating preference as across both conditions, the fluent grapes were preferred over the disfluent grapes.

This experiment also provides evidence for some memory of perceptual fluency processes that have been absent from my previous experiments. The assessment of the grapes for liking was not immediately after each trial when the grapes were disappearing. Rather, liking judgments were made at the end of the experiment where a static single grape was viewed for as long as participants required. Therefore, this is my first evidence for some learning and memory of prior perceptual fluency processes leaving a trace that can influence subsequent object assessments.

Experiment 7

The previous experiment established that a basic perception and inhibition game can manipulate preference, the next experiment in this paradigm develops the task to make it more 'game-like' by incorporating a touch screen. With advancements in technology, lots of games are played on tablets and phones which all use a touchscreen, and this is a necessary step towards an applied gaming environment where smartphone and tablet games often require a direct response to stimuli. The second benefit of using a touch screen is that it allows us to introduce motor-action fluency as a first investigation of combining fluency techniques while seeking stronger preference change effects.

This experiment addresses the question of whether combining techniques has an additive benefit on preference change. Each condition has different predictions. The inhibition condition is still testing a single mechanism. In this condition, the fluent grapes (not paired with stop-signal) and disfluent grapes (intermittently paired with stop-signal) disappear at the same rate. Therefore, adding a task of reaching towards and touching the disappearing grapes is equivalent across both types of grapes when the stop signal is not presented (all of the trials in the fluent condition and half of the trials in the disfluent condition). The stop-signal influences processes at the earlier reaction time stage (whether to release the key or not) and not during the reach towards disappearing targets. Here, introducing the motor act of reaching and touching a grape should be equivalent in both fluent and disfluent trials. Therefore, I predict that the addition of the new reaching task will have minimal impact on the ratings and the size of the preference effect will be equivalent to that of Experiment 6.

In the perception condition however, as the fluent and disfluent grapes disappear at different rates, when reaching for specific grape targets there is a greater chance the target will disappear before contact is made in the rapidly disappearing disfluent condition. This failure to obtain the current target, and re-direction of action to new targets, will be experienced as disfluent action. I predict that this combination of basic perceptual fluency of speed of presentation combined with motor disfluency while reaching will increase the preference for fluent versus disfluent grapes in the later assessment task. That is, the preference effect will be larger in Experiment 7 (perception + motor-action) than in Experiment 6 (perception alone).

Methods

Experiment 7 is a replication of Experiment 6 but with changes to the response method and the trial timings. The response method was changed from a keypress to a touch screen response, this change in the response method made the task more demanding so object disappearance rates and disgusted face appearance times were extended. Each change is explained in detail below.

Response method and task instructions

In Experiment 6, participants pressed the spacebar to make a response. In this experiment, participants responded to target objects differently. Participants began each trial by holding down the spacebar with the index finger of their dominant hand and then, as soon as they detected the targets were grapes, they released the spacebar and reached out to touch one of the grapes on the screen with the same finger that held the spacebar (See figure 18). Each target would still disappear one at a time and participants were told if the grape they were trying to reach had disappeared before they touched it, to try to get another until they were successful. As before, participants were not to respond if the targets were leaves or if the disgusted face appeared.

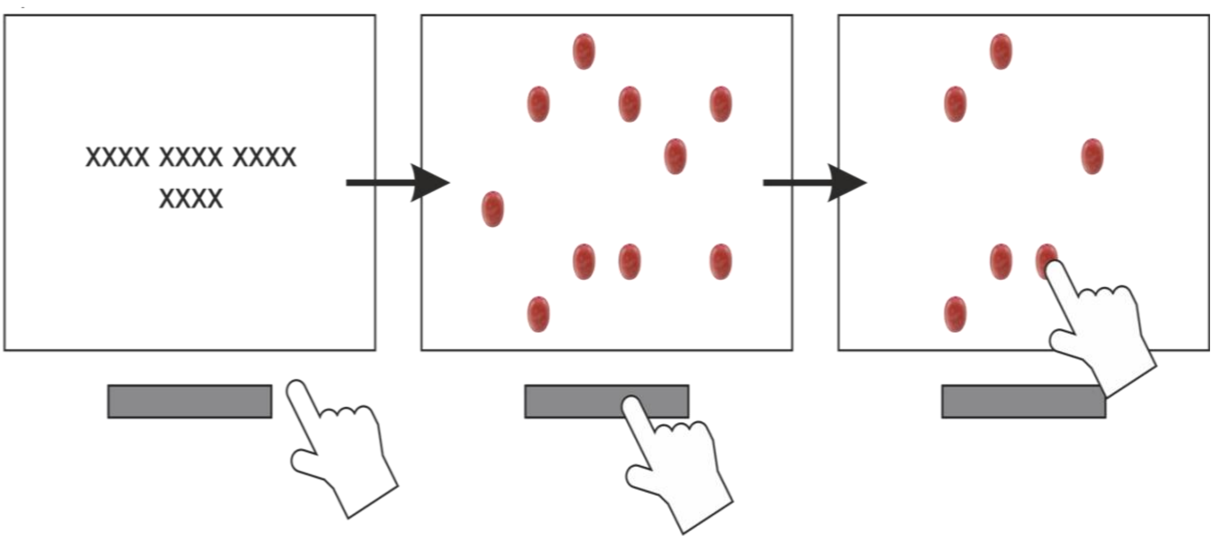


Figure 18. Experiment 7 response task. Participants press space bar if grapes appear. The left panel shows the screen at trial start and the right panel shows the participant pressing the space bar in the presence of grapes.

Perception condition.

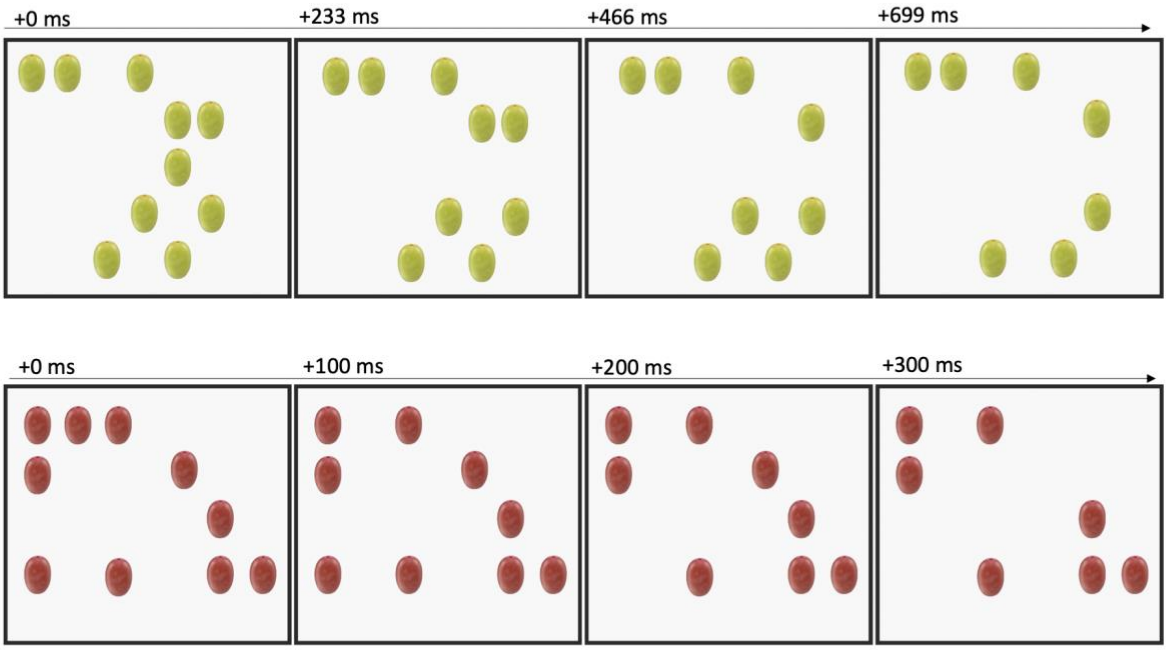


Figure 19 Schematic representation of perception condition. Top: a fluent trial where a grape disappears every 233ms. Bottom: disfluent fast grape trial where a grape disappears every 100ms. Note that the square black border was not shown during the experiment and is here for illustration only.

The perception condition (see figure 19) was identical to Experiment 6 aside from the trial timings: The fluent (slow) grapes disappeared at a rate of one every 233ms, the disfluent (fast) grapes disappeared at a rate of one every 100ms, and the leaves at one every 183ms to match the inhibition leaves.

Inhibition condition.

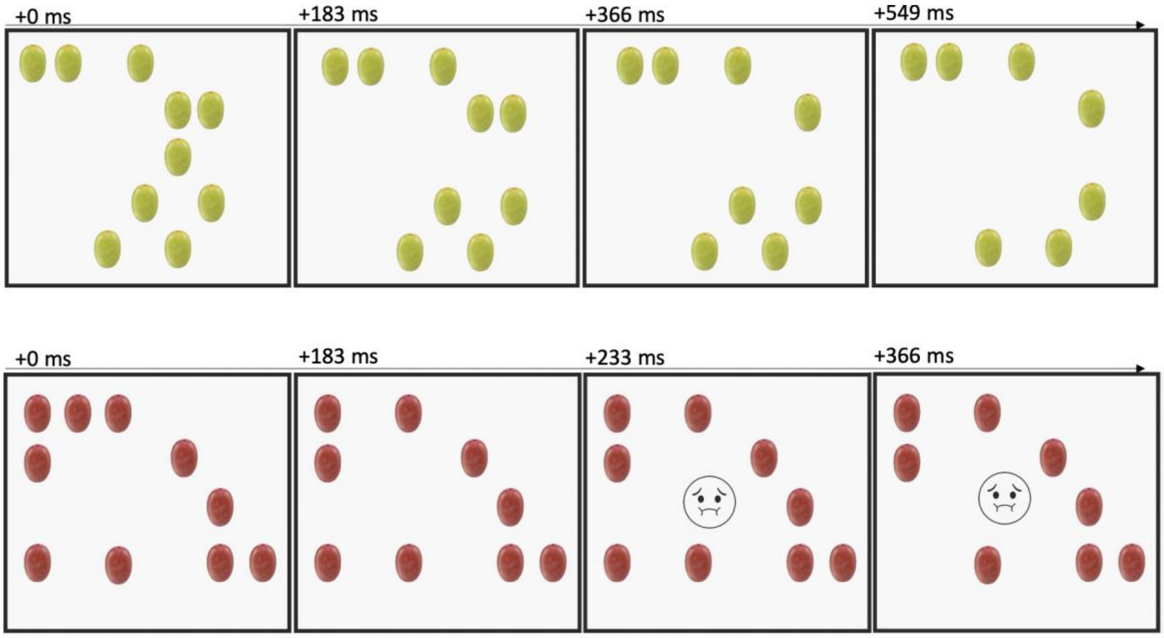


Figure 20 Schematic representation of inhibition condition trials. Bottom: a no-inhibition trial where a grape disappears every 183ms and the 'yucky face' appears 50ms after the first grape disappearance. Top: a go trial. Note that the square black border was not shown during the experiment and is drawn here for illustration only.

The inhibition condition (see figure 20) was identical to Experiment 6 aside from the trial timings: the grape disappearance rate was increased from 150ms to 183ms. The disgusted face still appeared 50ms after the first grape disappearance which was 233ms into the trial. The leaves disappeared at a rate of one every 183ms.

Participants

In the perception condition, 45 participants were tested, five participants were above the error threshold. The final sample consisted of 40 participants (4 males, age mean ± SD = 22.65±9.10), none of the remaining participants responded on more than 4 of 16 leaf trials (mean ± SD = 1.73 ± 1.20). In the inhibition condition, 42 participants were tested, two participants were above the error threshold. The final sample consisted of 40 participants (8 males, age mean ± SD = 19.76±1.36), none of the remaining participants responded on more than 3 of 16 leaf trials (mean ± SD = 0.63±0.93).

Results and discussion

To test the effect of perception and inhibition on preference, a mixed method 2 (fluent and disfluent) x 2 (perception and inhibition) ANOVA was conducted on the ratings (see figure 21). Results showed a main effect of fluency ($F(1,78) = 37.78$, $p < .001$, $\eta p^2 = .326$). There was no main effect of condition ($F(1,78) = .001$, $p = .970$, $\eta p^2 < .001$) and no interaction between fluency and condition fluency ($F(1,78) = .1.43$, $p = .235$, $\eta p^2 = .018$). These results replicate the findings of Experiment 6, fluent grapes were preferred over disfluent grapes and there was no difference in preference for the perception or inhibition condition.

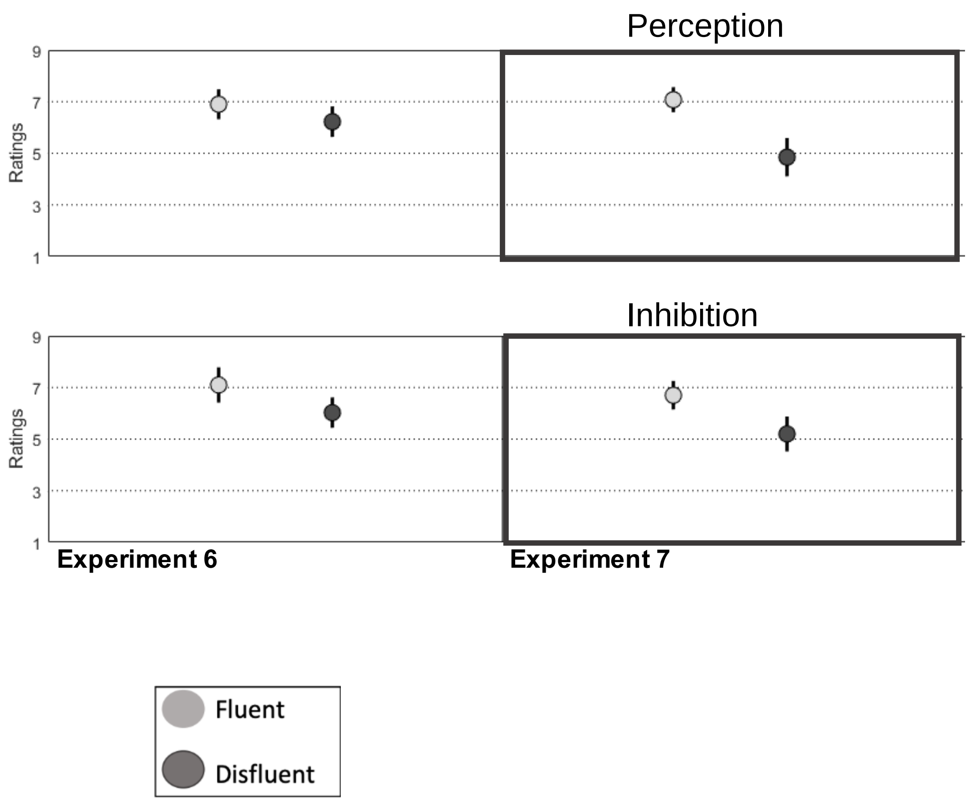


Figure 21. means and 95% confidence intervals for the preference ratings for Experiment 7, for the fluent (light grey) and disfluent grapes (dark grey). Perception condition is the top panel and inhibition is the bottom panel

Cross experiment analysis: Experiment 6 and 7

Experiments 6 and 7 both show that a short three-minute game can manipulate preference in the general population. In order to measure the impact of using multiple techniques on preference change, analysis was carried on preference ratings for Experiment 6 and Experiment 7. A mixed method 2 (fluency; fluent and disfluent grape ratings) x 2 (condition; perception and inhibition), x 2 (experiment type; button press vs touchscreen) ANOVA was conducted. Results showed a main effect of fluency ($F(1,156) = 44.23$, $p<.001$, $\eta p^2 = .222$), a main effect of experiment ($F(1,156 = 6.56$ $p=.011$, $\eta p^2 = .040$) and a significant interaction between fluency and experiment type $F(1,156) = 5.78$, $p=.017$, $\eta p^2 = .036$). There was no main effect of condition ($F(1,156) <.001$, $p=.979$, $\eta p^2 = <.001$), there was no interaction between fluency and condition ($F(1,156) = .16$, $p=.693$, $\eta p^2 =.001$), no interaction between experiment type and condition ($F(1,156) <.001$, $p=.979$, $\eta p^2 <.001$) and no interaction between fluency and experiment and condition ($F(1,156) = 1.88$, $p=.173$, $\eta p^2 = .012$).

To investigate the interaction between fluency and experiment type, two mixed methods ANOVAS were conducted on the perception and inhibition ratings separately. The first ANOVA was conducted on the perception conditions in Experiment 6 and Experiment 7 to see if the preference effect was larger when the game contained both perception and action fluency in comparison to just perception. A mixed method 2 (fluency; fluent and disfluent) x 2 (experiment type; key-press vs touch-screen) ANOVA showed a main effect of fluency ($F(1,78) = 24.672$, $p<.001$, $\eta p^2 = .240$) and as expected a significant interaction between fluency and experiment type ($F(1,78) = 7.05$ $p=.010$, $\eta p^2 = 083$), there was no main effect of experiment ($F(1,78) = 3.44$, $p=.067$, $\eta p^2 = .042$).

To better identify where the added effect of motor fluency influenced preference ratings, 2 paired samples t-tests were conducted to see if the ratings of fluent and disfluent grapes differed across experiments. Results showed that there was a significant difference in disfluent grape ratings for the perception condition between experiment 6 and 7 ($t(39) = -3.03$, $p=.004$, d =-.479) where preference significantly declined in Experiment 7 relative to Experiment 6. In contrast, there was no significant difference in fluent grape ratings for the perception condition in each experiment ($t(39) = .05$, $p=.590$, d =086). This supports the prediction that combination of basic perceptual fluency of speed of presentation combined with motor disfluency will decrease preference.

The second ANOVA was conducted on the inhibition ratings. As previously stated, the timings of the grape disappearance for both the fluent and disfluent grapes were equal across Experiment 6 and 7, the presence of the stop signal was the only manipulation. Therefore, it was predicted that there would be no difference in preference across the two experiments because upon response, the likelihood of success in the reaching action was equal for both fluent and disfluent grapes. A mixed method 2 (fluency; fluent and disfluent) x 2 (experiment type; key-press vs touch-screen) ANOVA showed a main effect of fluency ($F(1,78) = 19.86$, $p<.001$, $\eta p^2 = 203$), there was no main effect of experiment ($F(1,78) = 3.14$, $p=.080$, $\eta p^2 = 039$) and as predicted, no interaction between fluency and experiment type ($F(1,78) = .05$ $p=.464$, $\eta p^2 = 007$). This supports the prediction that the addition of the new reaching task will not impact the ratings and the size of the preference effect will be equivalent in Experiments 6 and 7. Figure 21 shows the change in ratings from Experiment 6 to Experiment 7.

Experiment 8

The results of Experiment 7 show that combining perception and action produced a more potent preference effect than perception alone. Because action fluency does appear to boost preference effects, and because reaching actions have ecological validity for potential future games, the reaching procedure is utilised in the remaining experiments in this thesis. The next experiment in this paradigm will combine perception, motor-action fluency and inhibition in the same trial to investigate whether there is any added benefit on adding a third technique for immediate preference manipulation, or whether two is just as effective. In this experiment, fluent grapes will disappear slower and will never be paired with the intermittent stop signal and the disfluent grapes will disappear quickly and be intermittently paired with a stop signal. The disfluent grapes will have perceptual disfluency, motor-action disfluency and inhibition. I do not know whether the addition of a third technique will be significantly different to two techniques on preference.

Methods

Experiment 8 is a combination of the individual perception and inhibition conditions of Experiment 7 where both perception and inhibition are experienced in the same trial, using the touch screen response method. The changes are highlighted below.

Experiment composition

As in Experiment 7, the experiment consisted of a practice block, a task block, and a rating block in that order All subjects participated in the single condition. Fluency was manipulated using both presentation time and stop-signal pairings.

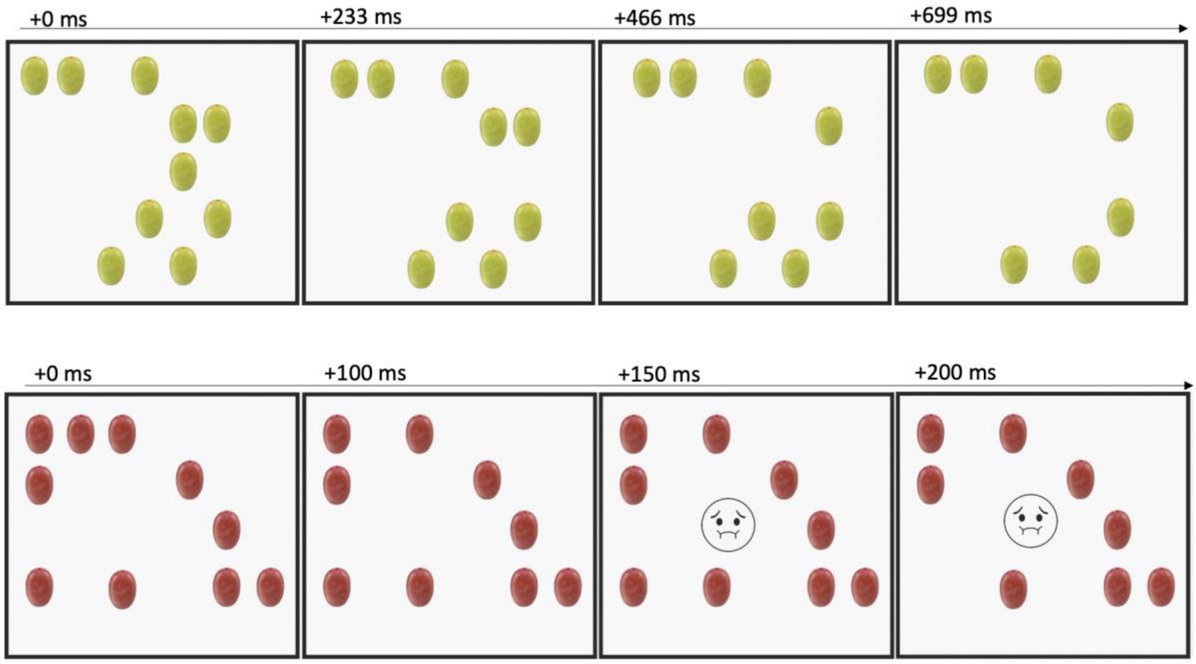


Figure 22. Schematic representation of a trial. Top, fluent grapes disappeared one every 233ms. Bottom, disfluent grapes disappeared one every 100ms and on 50% trials a yucky face appeared 50ms after the first grape disappearance. Top: a go trial.

Trial composition and timings

The fluent (slow) grapes disappeared at a rate of one every 233ms and were never paired with the disgusted face, the disfluent (fast) grapes disappeared at a rate of one every 100ms and were paired with the disgusted face on 50% trials, the disgusted face still appeared 50ms after the first grape disappearance which was 150ms into the trial and the disappeared at a rate of l one every 183ms (see figure 22).

The practice block consisted of 4 grape and 2 leaf trials. Half of the grape trials and half of the leaf trials were green with the others red. Half of the trials for one colour of grape featured the stop-signal. The experiment block consisted of exactly the same amount of trials as the previous experiment.

Participants

41 participants were tested, one participant was removed from the analysis as they failed to complete the experiment. The final sample consisted of 40 participants (4 males, age mean ± SD = 20.43±1.75). No participants responded on more than 3 of 16 leaf trials (mean ± SD = 0.68 ± 0.86).

Results and discussion

To test the effect of perception, motor-action fluency and inhibition on preference, a paired sample t-test was conducted on the preference ratings (see figure 23). Results showed that the fluent grapes were significantly preferred over disfluent grapes ($t(39) = 4.79$, $p < .001$, $d = .757$).

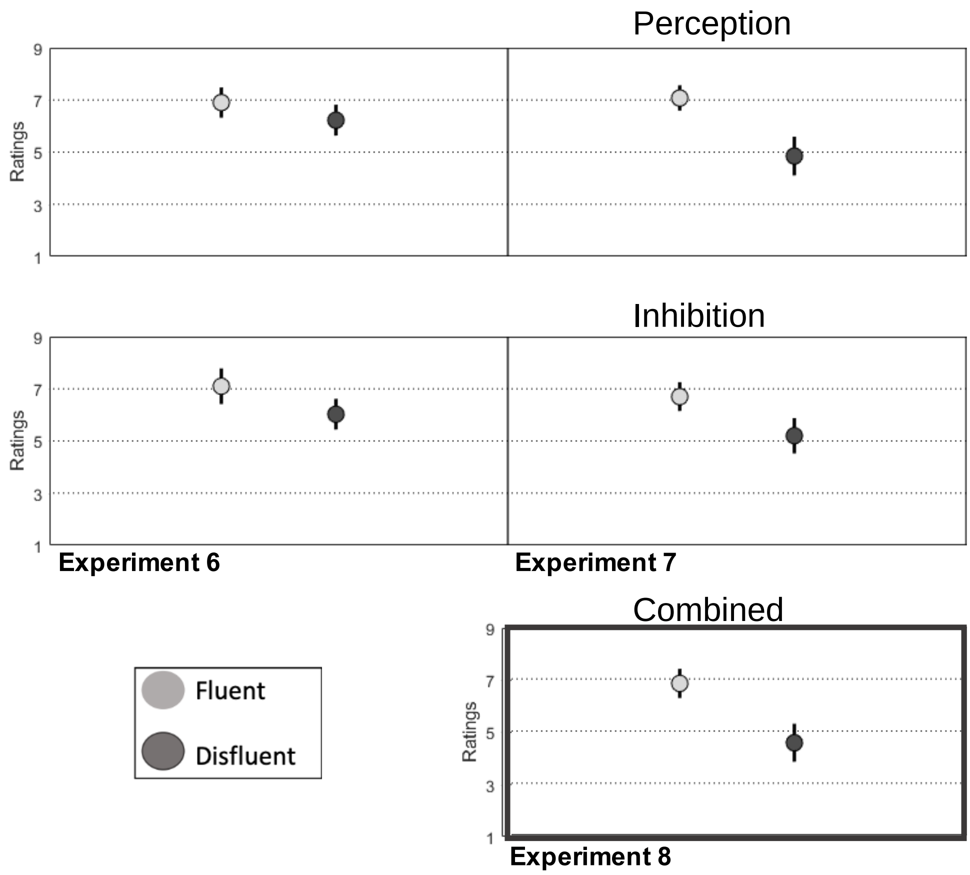


Figure 23. means and 95% confidence intervals for the preference ratings for Experiment 8, for the fluent (light grey) and disfluent grapes (dark grey).

Cross experiment analysis: Experiment 7 and 8

To assess the impact of combining techniques (perception and inhibition) in comparison to the conditions in Experiment 7, a 3 x 2 ANOVA was conducted on the ratings from Experiment 8 and Experiment 7. Results showed a main effect of fluency ($F(1,117) = 60.72$, $p < .001$, $\eta p^2 = .342$). There was no main effect of condition ($F(2,117) = .45$, $p = .638$, $\eta p^2 = .008$) and no interaction between fluency and condition fluency ($F(2,117) = .95$, $p = .389$, $\eta p^2 = .016$).

The results from this experiment are somewhat counter-intuitive findings concerning the combined perception + inhibition condition. The initial hypothesis was that combining the perceptual fluency and inhibition would produce more robust preference changes than either alone. This clearly was not the case. It is possible that the effects in the current experiment are at ceiling. That is, the preference rating task is a few seconds after the completion of the experimental game task, and hence even though combined techniques might indeed be more robust, that cannot be detected in these short interval conditions.

General discussion

The studies in this chapter examined manipulations of perception, motor-action fluency and inhibition, and the potential additive effects of these on immediate preference judgments. From these aims, two main questions were explored. First, can the perception and inhibition task manipulate preference in a short 3-minute game? The second question investigated whether combining approaches produce more stable and robust preference changes than using either technique in isolation? Each question will be discussed in turn.

The results from Experiment 6 show that a short 3-minute game using perception and inhibition is successful in manipulating preference. In the perception condition, fast disappearing grapes were liked less than slow disappearing grapes and in the inhibition condition, grapes that were intermittently paired with the stop signal were liked less than the grapes that were always responded to, confirming previous findings (Houben & Jansen, 2015; Houben et al., 2010; Wessel et al., 2014).

In the perception condition, the disfluent grape ratings were significantly lower when perception and motor-action fluency were combined in the reach-to-target task (Experiment 7) in comparison with the perception alone simple key press response (Experiment 6). This suggests that the addition of the reach and touch motion when the grapes were disappearing quickly, where motor correction was more likely, implicitly devalued the disfluent grape. This finding is in line with research by Hayes, et al (2008) and Cannon et al (2010) showing that motor-action fluency can have an impact on preference when participants are interacting with the stimuli, and that motor disfluency/conflict could be retrieved from memory (e.g., Beilock & Holt 2007).

However, in contrast to the apparent additivity of perception and action fluency, Experiment 8 showed that combining perception and inhibition had no effects. That is, in similar reach-to-target tasks, when the disfluent stimulus possessed disfluent perception (faster disappearance rate) and stop-signal inhibition, there was no increase in the preference for fluent versus disfluent stimuli. It is possible that because the preference decision was immediately, within seconds of completing the grape catching game, the effects were at ceiling. Therefore, the experiments in the following chapter provide a more demanding memory challenge to further examine whether combining perception and inhibition can produce additive effects.

In summary, although it was noted above that inhibition techniques have previously been shown to change preference at a later time beyond the experimental context, no such effects have been observed in the perception literature, where judgments are typically made in the moment while viewing a stimulus (Flavell, Over, & Tipper, 2019; Flavell, Tipper, et al., 2018). And indeed, the experiments examining the effects of motion fluency described in Chapter 2 and 3 in this thesis, also failed to show generalization beyond the stimulus properties. However, in the current experiments I have now, for the first time, shown perceptual effects at a later time outside the experimental context. This is an important first step towards potential application of perceptual-motor approaches to preference change. The next chapter investigates whether effects can be detected over longer periods and changes of context and stimulus.

Chapter 5: Time delayed preference

Introduction

To reiterate the focus of my thesis, the ability to change an individual's behaviour has significant potential for many of the issues of the day, from changes in lifestyle to reduce energy consumption (Team BI, 2011) and improved diet (e.g., Houben, 2011) to reducing interpersonal conflict (e.g., Martiny-Huenger, Gollwitzer, & Oettingen, 2014). One route to such behaviour change is to influence preference and choice, where an increase in preference for stimuli such as healthier foods can lead to increased healthy food consumption and improvements in health. This issue is approached by considering the basic visual-motor processes that could be potentially manipulated while playing computer games.

Games to change behaviour have proliferated in recent years. In particular, brain training games purported to improve cognitive processes have been widely promoted. However, there has been much debate concerning whether such games can change behaviour in a broad and general manner. A meta-analytic review by Sala et al (2018) suggests changes are domain specific and rarely generalize to wider situations. Similarly, Brox, Fernandez-Luque, & Tøllefsen, (2011), in reviewing video games designed to improve health, concluded that there is not enough evidence to decide which design principles are most effective as there is limited specification of design methodologies.

The experiments in the previous chapter investigated immediate preference shift using a short 3-minute game-like task to manipulate preference of food stimuli. Across three experiments, games using perceptual fluency and inhibition successfully manipulated preference and there was no additive benefit of combining both fluency and inhibition for immediate preference change. The experiment in this chapter focuses on three key challenges to the memory trace of the fluency/inhibition associations, the first being a change in rating system, from pictures on a screen to tasting real life stimuli that appear in the game. The second being a change in rating environment, all previous experiments have rated the stimuli in the environment where the exposure phase took place. Finally, the time course of the memory trace is examined, where rather than immediate preference decisions after the game, a 20-minute delay is included.

The first challenge looks at whether the associations formed in the game will generalise to real life preference. Previously, participants rated pictures of the stimuli, whereas this experiment has a more ecologically valid measure and participants will rate the taste of stimuli they are exposed to in the game. There is some evidence in the literature that suggest preference can transfer from the exposed stimuli to a different, related stimuli. Research by Johnston, (2016) tested the transfer or preference from familiar to unfamiliar music, participants were exposed to a set of music examples across a 5-week period, liking ratings at the end of the exposure were significantly higher than pre-test and this preference also transferred to similar sounding music. Contrasting research found evidence for associative transfer, but only when participants were aware of the CS-US pairings. In this study, gender neutral names were repeatedly paired with obviously male or female children in the exposure phase and in the test phase participants had to rate just the gender of the name. Results showed that there was a transfer from the gender of the child that the name was paired with but only in the participants who were consciously aware of the CS (child's gender) and US (neutral name) pairings (Meersmans, De Houwer, Baeyens, Randell, & Eelen, 2005). These few examples show how aspects of evaluative conditioning can transfer onto nonevaluative stimuli properties, however, seemingly participants are aware of the associations.

The second challenge looks at whether the associations formed in the game can be retrieved in a new environment. In the previous experiment, participants played the game and rated the stimuli in the same room, in the next experiment the associative learning of the object-fluency/inhibition pairings are tested in a new context. This is a challenge to the memory trace of the affect because the context-dependent memory hypothesis suggests that recall is better if the same environment is experienced during learning and later retrieval (Godden & Baddeley, 1975). And of course, for practical use of behaviour change, learning effects would have to transfer between different environments, such as the bedroom to the dining room, when changing food preferences for example.

Finally, the last challenge is a time-delay between playing the exposure phase and the rating. Previously, the participants rated the stimuli immediately after the exposure phase for liking. In the perceptual fluency literature, judgements are typically made in the moment (Flavell, Over & Tipper, 2019; Flavell, Tipper & Over, 2018), on a trial-by-trial basis, rather than at the end of an experiment. And in contrast to the evidence from studies of inhibition (Houben & Jansen, 2015; Houben et al., 2010; Lawrence, O'Sullivan, et al., 2015; Nederkoorn et al., 2010; Veling et al., 2011), little evidence that effects can be detected outside immediate perceptual fluency experience.

From these three challeneges, the experiment sets out three questions: first, does the preference formed in the game generalise to real world taste preference? Second, does the preference affect survive a context change? Finally, does the preference affect survive a time-delay.

Experiment 9

The game-like task in Experiment 9 is identical to that of Experiment 7 and 8, with just a minor change in stimuli from grapes to coloured drinks. However, Experiment 9 is a much more severe challenge of learning and memory retrieval. This is of fundamental importance if techniques embedded in games are to have real-world effects on preference and choice. Therefore, in Experiment 9 a number of significant changes are made following completion of the task/game. First, after completing the 3-minute game participants engage with a completely different task for ~20 minutes, rather than immediately making a preference judgement. This task takes place in a new room, to change environmental context (Baddeley & Hitch, 1993; Godden & Baddeley, 1975). After completing the new task, participants then move in to yet another new room, further increasing changes in environmental context. Finally, and of perhaps most importance, preference judgements are made with real-world stimuli. That is, they are presented with drinks to taste and make preference judgments on. For games to be effective, a crucial step is for transfer from the images of objects on the computer screen to real-world objects that can be consumed.

Method

The experimental procedure was a combination of Experiment 7 and 8 in the previous chapter with the changes stated below.

Practice, task, rating and interview blocks

Before the practice block participants were told that they would complete several unrelated experiments in different rooms. Participants completed the practice and task blocks as described in Experiment 7 (perception and inhibition) and 8 (combined perception and inhibition) but the object images were changed from grapes and leaves to drinks in cups and outlines of cups-to-be-ignored (see Figure 24 and Stimuli). The instructions were changed to match these new terms. The practice and task block took place in the same room as in Experiments 7 and 8. After completing these blocks participants were taken to a second room where they completed an unrelated visual search task for ~20 minutes. They were then taken to a third room where they completed a surprise rating block.

The rating block was completed in a lit room at a white desk with a white backdrop. On the desk were two cups of coloured water (see Stimuli) set ~30cm back from the seating edge and ~50mm separate from each other. Whether the fluent (i.e. slow disappearing and/or stop-signal association) drink was on the left or right was counterbalanced within conditions. In front of each drink was a paper 9-point Likert scale, and between these was a ball point pen. Participants were seated centrally in front of the drinks and asked to try both the drinks, drink as much as they liked and rate how much they liked the taste of each. The researcher then left the room whilst ratings were made but surreptitiously waited to see which drink was picked up first. In addition to the rating of each drink, we also analysed which drink was picked up first and the volume consumed of each drink.

After completing the rating task participants completed a surprise funnel interview to explore explicit noticing of the experimental manipulation. All participants were first asked an open-ended question ‘Did you notice anything about the game you played with the drinks and the cups?’. The follow up question then depended on condition. In the perception condition, participants were asked ‘One of the drinks disappeared quicker than the other, was this the green or blue drink?’. In the inhibition condition, participants were asked ‘One of the drinks was always paired with the yucky face, was this the green or blue drink?'. In the combined condition participants were asked both of those questions.

Stimuli

When transferring to real-world object assessments, for health and safety reasons we substituted green and red grapes for cups of green and blue dyed water. Green and red leaves were substituted for green and blue outlines of those cups so that they presented the same profile. The cups were transparent plastic cups filled with 400g of water. Colour was controlled using set volumes of food dye which were determined before data collection so that both drinks would be similarly vivid yet transparent. These drinks were photographed from the same perspective for use as stimuli in the computer game. The outline images were closely colour matched to the corresponding liquid colour using CorelDraw 2018 v20 (Corel Corporation, Ottawa, Canada). See Figure 1D.

As in Experiment 7 and 8 participants rated only the test objects in the rating block. These drinks were prepared in exactly the same way as those photographed for the practice and task blocks.

Figure 24. Experiment 9 stimuli.

Data exclusion and analysis

Participants were excluded if they responded on >25% of outline trials in the task block and if they did not complete the taste test. Only rating block data and correct trials in the task block were analysed. The practice and task blocks took ~3 minutes to complete, and the rating block began ~21 minutes later.

Participants

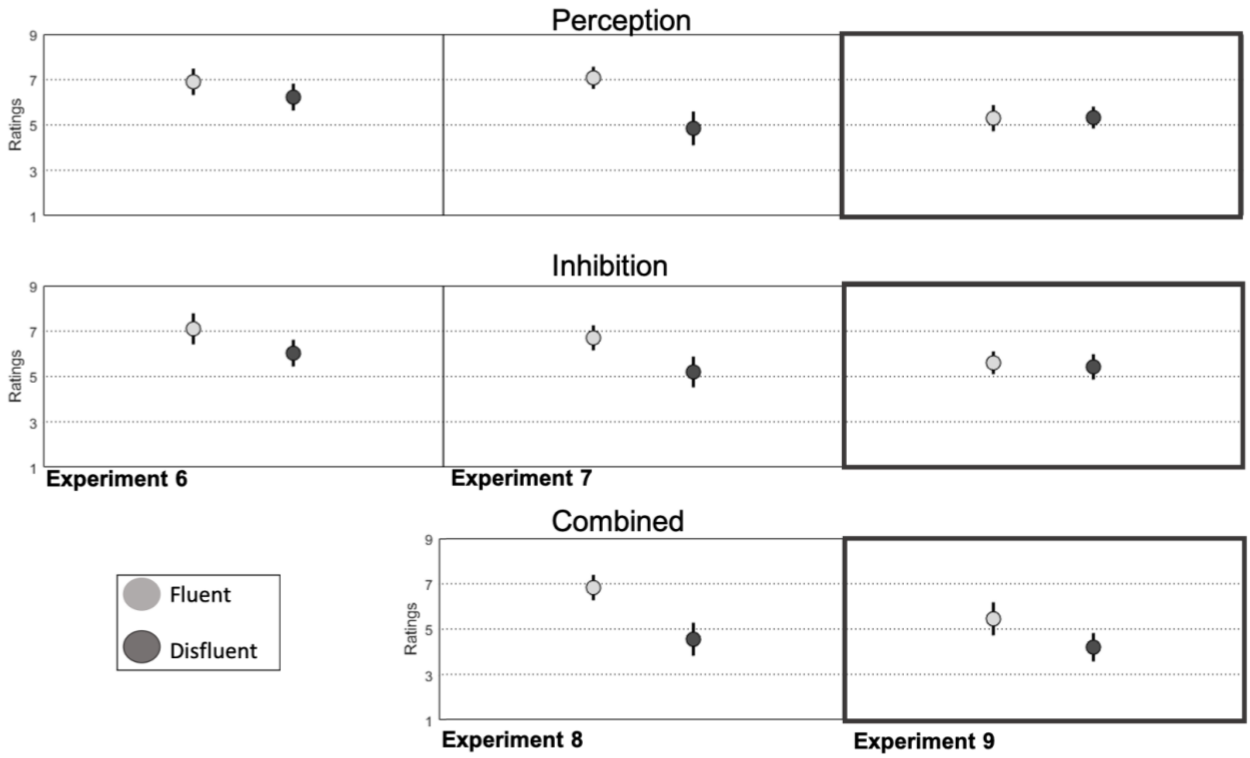
In the perception condition, 43 participants were tested. One participant exceeded the error threshold and two participants did not complete the taste test giving a final sample of 40 participants (4 males, 5 did not disclose gender, age mean ± SD = 19.9±3.4) with none responding on more than 3 of 16 cup trials (mean ± SD = 1.1 ± 0.9). In the inhibition condition 41 participants were tested. One participant did not complete the taste test giving a final sample of 40 participants (8 male, 5 did not disclose, age mean ± SD = 21.0±6.8) with none responding on more than 3 of 16 cup trials (mean ± SD = 0.4 ± 0.7). In the combined condition 41 participants were tested, one participant did not complete the taste test giving a final sample of 40 participants (5 male, 5 did not disclose, age mean ± SD = 21.9±15.8) with none responding on more than 3 of 16 cup trials (mean ± SD = 0.7 ± 0.9).

Results

Taste ratings

To test the effect of perception, inhibition and the combined perception and inhibition on preference, a 3 (condition: perception, inhibition and combined) x 2 (fluency: fluent and disfluent) ANOVA was conducted on the ratings. Results showed a main effect of fluency ($F(1,117) = 7.11$, $p = .009$, $n^2_p = .057$) and a significant interaction between fluency and condition ($F(2,117) = 5.12$, $p = .007$, $n^2_p = .080$), however there was no main effect of condition ($F(2,117) = 1.93$, $p = .150$, $n^2_p = .032$).

Figure 25. means and 95% confidence intervals for the preference ratings for the fluent and disfluent grapes in the perception (top), inhibition (middle) and combined (bottom) condition.



To investigate the interaction and to see where the fluency ratings differ across conditions, three paired samples t-tests were conducted on each condition. Results showed that there was a significant difference in preference for the fluent over the disfluent drinks in the combined condition ($t(39) = 3.33$, $p = .002$, $d = .527$), however there was no difference in preference between the fluent or disfluent drinks in the inhibition ($t(39) = .71$, $p = .484$, $d = .112$) or perception condition ($t(39) = -.09$, $p = .93$, $d = -.015$). These results show that there was only a difference in preference for the combined inhibition and perception condition, rather than each condition on their own.

Drink picked first

Note that several data points were missing where it was not possible for the experimenter to surreptitiously take note of which drink was chosen first. Binomial tests (test value = 0.5) indicated that the proportion of participants who chose to taste the fluent associated drink first was not significantly different to the proportion who chose to taste the disfluent drink first in both the perception (51.4% chose the fluent first, p=1.00, n = 37) and inhibition condition (53.8% chose the fluent first, p=. 749, n = 39). However, there was a significant difference in the proportion of participants who chose to taste the fluent associated drink first in the combined condition (67.5% chose the fluent first, p=.038, n = 40).

Similarly, the proportion of participants who chose to taste the blue drink first was not significantly different to the proportion who chose to taste the green drink first: perception (p= .188, 62.2% chose blue first); inhibition (p= .749, 53.8% chose blue first); and combined (p= .636, 55% chose blue first).

Volume consumed

To assess how much of the perception and inhibition associated drinks were consumed for each condition, a 3 (condition: perception, inhibition and combined) x 2 (fluency: fluent and disfluent) ANOVA was conducted on the consumption of the drinks. Results showed no main effect of fluency ($F(1,117)$ =2.57, p = .111, n^2_p =.022), no main effect of condition ($F(2,117)$ =.91, p = .405, n^2_p =.015) and no interaction between fluency and condition ($F(2,117)$ =.05, p = .948, n^2_p =.001). Results show that there was no difference in consumption for the fluent or disfluent drinks in the perception, inhibition or combined condition.

Funnel interview (explicit awareness)

Responses to interview questions were analysed using binomial tests (test value = 0.5). In the perception condition, the proportion of participant who correctly identified the manipulation did not differ from the proportion who didn't (p = .154, 37.5% correct). Of the participants who did not correctly identify the manipulation (n = 25), the proportion of participants who correctly answered which drink colour disappeared faster did not differ from the proportion who didn't (*p* = 1.00, 48% correct).

In the inhibition condition, the proportion of participants who correctly identified the manipulation was smaller than the proportion who didn't (*p* = .002, 25% correct). Of the participants who did not correctly identify the manipulation (though 30 participants erred, 1 data was missing from this subset meaning only 29 participants were analysed), the proportion of participants who correctly answered which drink colour was paired with the yucky face did not differ from the proportion who didn't (, *p* = 1.00, 51.7%).

In the combined condition, the proportion of participants who correctly identified the manipulations was smaller than the proportion who didn't (*p* = .038, 32.5% correct). Of the participants who did not correctly identify the manipulation (n = 27), the proportion of participants who correctly answered which drink colour was paired with the yucky face did not differ from the proportion who didn't (*p* = 1.00, 48.1%), and the proportion of participants who correctly answered which drink colour disappeared faster did not differ from the proportion who didn't (*p* = .248, , 37%).

In summary, there no evidence that participants were above chance at identifying the experimental manipulations in any condition.

Discussion

The experiment in this chapter examined manipulations of perception and motor-action fluency, inhibition and a combination of the two approaches to test a delayed effect on preference. Participants completed the exposure phase of the experiment where they were responding to drinks and ignoring empty cups, were then taken to a separate room for a 20-minute unrelated filler task and then were moved to a final room to make taste preference ratings of real drinks, like the ones they were responding to in the exposure phase. Three research questions were outlined before the experiment. first, does the preference formed in the game generalise to real world taste preference? Second, does the preference affect survive a context change? Finally, does the preference affect survive a time-delay.

The results of Experiment 9 are in sharp contrast to those of Experiment 7 and 8. Recall that in Experiment 7, when preference judgments were made immediately after completing the experiment/game, clear effects of perceptual fluency and inhibition were observed, and in Experiment 8, there was no advantage when these techniques were combined. However, the effects dramatically change in Experiment 9 which features more severe memory challenges of longer task filled intervals, a change of environmental context, and transfer from on-screen images to real-world objects. Now the previously robust perceptual fluency and inhibition effects on preference are no longer detected. Hence, although this short 3-minute task can in principle alter preference, the effects of the individual techniques are fragile. However, it's now discovered that when these techniques are combined within the same block of trials, preference change is indeed more robust.

Examining preference effects while interacting with real-world objects such as drinks enabled me to measure two other possible preference changes via implicit approaches that did not require participants to introspectively interrogate their preferences. The first of these was the amount of drink consumed, where it might be hypothesised that more of the preferred drink would be consumed. However, we did not detect any differences in consumption rates between drinks previously associated with fluent or disfluent processing. One possible reason this was not detected is due to floor effects. The drinks were tap water that was not very appealing, and only 26ml was consumed on average, which equates to a couple of small sips. On the other hand, the second implicit measure of which drink was picked up first did support the explicit preference rating results. No differences were detected for the individual perception and inhibition conditions, but there was evidence for a greater proportion of participants picking up the fluent/uninhibited drink first in the combined perception + inhibition condition. That is, after drinks were associated with both disfluent perceptual processes (faster presentations) and stop signal inhibition, participants were less likely to taste them first.

As a final comment, which must be tentative at this stage, the majority of participants appear to have little knowledge of the game properties that might have influenced their later preference decisions. That is, the majority of people could not report anything about the perceptual and/or inhibition features of the game. And even when provided information about what these game properties were, they still could not explicitly identify which drink was associated with disfluent processing. Although the issue of awareness requires much more work, it is intriguing that the visuomotor processes that might be embedded in games might be able to change preferences without awareness.

A central goal of this research was to examine whether preference can be changed in very short periods. The task described here was completed in approximately 3 minutes and each fluent or disfluent stimulus was only presented 16 times. This is a very challenging test of the perceptual fluency and inhibition mechanisms. Somewhat surprisingly, both perceptual fluency and inhibition do change preference very rapidly, if the assessment is made immediately after completing the game. For more stable longer-term effects that generalize to new contexts and stimuli, I have now demonstrated for the first time that combining techniques is more effective.

Chapter 6: General discussion

The experiments in this thesis investigated the efficacy of using basic cognitive processes of perceptual fluency and inhibition to bias preference and choice behaviour. This general discussion will summarise the main aims and findings of the thesis, highlight the significance of the findings, discuss the differences found in the experimental chapters and finally propose future research.

Motion fluency summary

As previously stated, much of the perceptual fluency research has focused on static stimuli (e.g. Bertamini et al., 2013; Flavell, Tipper, & Over, 2018; Makin et al., 2012;Reber & Schwarz, 2001). However, motion is a fundamental stimulus property that could evoke fluent or disfluent processing states and one that can readily be used in a gaming context. The first half of the thesis focuses on motion research where the stimulus itself possesses moving properties. The first aim examined whether motion fluency effects can be observed and the second examined whether the associations between an object's identity and its pattern of motion can be learned and generalised to other stimulus situations. Each aim will be discussed in turn.

Chapters 2 and 3 have shown a robust fluency affect where fluent smooth, predictable motion is consistently preferred over disfluent not-smooth, unpredictable motion. This finding was only observed when participants rated the object following a moving presentation. In Experiment 1, participants rated motion stimuli and there was a significant preference for the fluent in comparison to the disfluent associated stimuli at both the first and final rating. This shows that the motion fluency affect is potent as it was observed on the first exposure to the motion. The lack of interaction between fluency and exposure suggests that there is little learning and that a potential ceiling/floor effect was found, and it would be difficult to detect increases/decreases in preference. A similar pattern of results is seen in the motion ratings in Experiment 3, there was a significant preference for the fluent in comparison to the disfluent associated stimuli at the first and final rating. However, in comparison to Experiment 1, there was a significant increase in preference for the fluent objects at the final rating. This effect indicates an associative learning and memory retrieval as the fluent stimuli preference increased following multiple exposures. Finally, a weaker effect was observed in Experiment 5; there was still a significant preference for the fluent in comparison to the disfluent associated stimuli, but this was at the final rating only. This weaker effect could be due to the stimuli as they were winged insects instead of the generic geometric shapes used in the previous experiments. Participant's previous experience of the insects could have biased the ratings at the first exposure, whereas the final ratings could have been influenced by the object-motion pairings. This again suggests that there is evidence for associative learning as the preference for fluent in comparison to disfluent associated stimuli was observed after repeated exposures. The results in Chapters 2 and 3 support the aim that motion fluency affects can be observed and is a robust effect because it was found in Experiment 1 and replicated in Experiment 3 and 5.

Whilst a robust fluency effect was found when rating the moving stimuli, the associative learning of the object-motion pairs seems to be limited and context dependent. That is, when objects were rated following a static presentation, participant's preference ratings were unaffected by previously exposed object-motion pairs. Chapters 2 and 3 found consistent null results for the static associated stimuli. In Experiment 2 there was no preference for either the fluent or disfluent associated stimuli following a static presentation at the final rating. A significant interaction between fluency and exposure was found which was driven by a decrease in preference for the fluent associated stimuli from the first to the final rating. However, there was no difference in preference between the fluent or disfluent associated stimuli at the first or final rating. This interaction was an unexpected finding and opposite to the hypothesis prediction. Similarly, Experiment 3 also showed no preference for fluent or disfluent associated stimuli at the first or final rating and there was no significant interaction. Experiment 4 had a change of response task from a single button press to a two alternative forced choice task to encourage deeper encoding of the object-motion pairings. However, replicating Experiment 3, there was no preference for either the fluent or disfluent associated stimuli at the first or final rating. Finally, Experiment 5 used the task from Experiment 4, changed the stimuli from generic geometric shapes to winged insects and increased the sample size to further encourage associative learning of the object-motion pairings. Replicating Experiments 3 and 4, there was no preference for either the fluent or disfluent associated stimuli at the first or final rating. This indicates that any learning of the object-motion pairings was either undetectable or irretrievable from memory following a context change from motion presentation to static presentation. The significant interaction found in Experiment 2 has not been replicated in either Experiment 3, 4 or 5 and therefore cannot be seen as evidence for associative learning.

These results do not support the second aim and show that retrieval of prior associations between an object's identity and its pattern of motion does not transfer to new contexts where motion is no longer observed. This finding contrasts the well-established literature of evaluative conditioning.

To sum up the results from the first half of the thesis, the experiments in Chapters 2 and 3 have found that motion fluency is a robust method for manipulating preference only when the stimuli is rated following a moving presentation. There appears to be some evidence for associative learning after prior exposures as the ratings for the final exposure were different in Experiments 3 and 5 for the motion stimuli. The absence of the fluency affects for the static stimuli is an important finding for the field of visuomotor fluency as it shows that it is possible to bias preference in the moment, however, this is potentially short lived and is not strong enough to survive a context change. This is a key finding because without the ability to transfer to different contexts, it cannot meaningfully impact behaviour. This is an interesting boundary condition that should be considered when applying research to real-world behaviour change. If the motion fluency preference effect vanishes following a small context change then any learned preference is unlikely to transfer, limiting the efficacy of using motion to bias preference. Chapters 2 and 3 failed to find evidence for associative learning and retrieval from memory for object-motion pairs. Across 5 experiments I have attempted to strengthen the associations using both a within-subject and between-subject design, utilised two different tasks where the latter encourages more participant engagement, increased the sample size and finally tested two different sets of stimuli, one with distinctive geometrical shapes and the other that readily move in the environment. However, the results show a robust fluency affect and a fragile memory effect.

Perception, motor-action fluency and inhibition summary

The second half of the thesis investigated perceptual fluency through presentation time, motor-action fluency and stop-signal inhibition in a short 3-minute game like task to bias preference. This half of the thesis had two main aims, to assess immediate and time-delayed preference, each will be discussed in turn. Chapter 4 moved towards real-world preferences by using a more engaging game-like task and food stimuli. This chapter aimed to set the baseline to investigate whether compressing perceptual fluency and inhibition into a short task was still effective in biasing preference. These techniques often use longer training programmes or require participants to rate the stimuli after every exposure. Experiment 6 tested these techniques in a short 3-minute task where participants rated the stimuli once after the exposure phase. Results showed that the task was effective in biasing preference as there was a main effect of fluency where fluent associated grapes were rated higher than disfluent associated grapes. There was no interaction between fluency and condition, suggesting that the preference was similar across the perception and inhibition conditions. These results show that using a short version of both perceptual fluency and inhibition can be an effective way to bias preference. Experiment 6 provides evidence of memory for perceptual processes, a finding that is absent from the motion fluency work highlighted above. The liking ratings are not on a trial-by-trial basis, rather momentarily at the end of the experiment where a single presentation of a grape is rated. Therefore, this provides a basis for memory of prior perceptual processes leaving a trace that influences future object assessments.

Once the paradigm was deemed effective in biasing preference, Experiment 7 focused on the first step towards combining techniques together. Thus far, the literature on preference bias has focused on a single technique, to my knowledge, there has been no attempt at combining techniques. This experiment combined motor-action fluency with perception in one condition and similar to Experiment 6 also had an inhibition only condition. Replicating Experiment 6, results showed a main effect of fluency with fluent associated grapes receiving a higher liking rating than disfluent associated grapes in both the perception and motor-action condition and the inhibition condition. Similarly, there was no interaction between fluency and condition type. The liking ratings for the disfluent associated grapes were significantly lower when comparing the combined motor-action fluency and perception condition, in comparison to the perception only condition. This indicates an additive benefit of using two or more techniques on preference bias.

Experiment 8 combined all three techniques into one task to see whether there was any immediate benefit of combining more than one technique to bias preference. Results showed a significant preference for the fluent associated grapes in comparison to the disfluent associated grapes. However, when comparing the results of Experiment 8 with the combined perception and motor-action fluency condition of Experiment 7, there was no difference in liking ratings for each condition. This is somewhat counterintuitive, suggesting that the addition of another technique had no additive benefit on immediate preference. One idea could be that the effects are currently at ceiling and three techniques might be more robust than two, however the short interval of immediate rating might not have been able to detect it.

Finally, Chapter 5 challenged the learning and memory retrieval of the fluency and inhibition affect shown in Experiment 7. This is important if the techniques embedded into games can have a real-world impact on preference and choice. Experiment 9 used the perception + motor-action fluency, the inhibition conditions from Experiment 7 and the perception + motor-action fluency + inhibition combined condition from Experiment 8 and made key changes following the completion of the task/game. First, after completing the 3-minute game, participants engaged in a 20-minute unrelated filler task in a new environmental context. Then participants moved to another new room to increase the changes in environmental context. Finally, the preference judgements were made on real-world stimuli, participants were given drinks to taste and make preference judgements on. Preference rating results showed a higher subjective liking rating for fluent associated drinks in comparison to disfluent associated drinks in the combined condition alone. This finding was absent from the other two conditions. Similarly, in the combined condition, participants picked the fluently associated drink to taste first significantly more than the disfluently associated drink, indicating an implicit preference. Again, this finding was absent in the other two conditions. Finally, across all conditions, participants were seemingly unaware of the experimental manipulations, suggesting that the manipulations were working at an implicit level, outside of conscious awareness.

The results of Experiment 9 are contrasting that of Experiment 8 as there was no advantage of combining techniques. However, this is drastically changed when pushing the memory and environmental challenges seen in Experiment 9. This shows that the individual techniques are fragile in the long-term and combining techniques adds robustness to the preference bias.

Comparing the experimental chapters

The lack of context transfer or retrieval from memory shown in the motion fluency work in Chapters 2 and 3 is contrasting to the work using perception, motor-action fluency and inhibition in Chapters 4 and 5. There are a number of reasons why the two halves of the thesis have different findings.

The first point to consider is that the manipulation used in the grape experiment was fluency through presentation timing and this could be a stronger preference bias than motion fluency. The literature using presentation time to bias preference is an already established field with research showing that stimuli associated with longer presentation times yielded higher subjective liking than stimuli associated with shorter presentation times (Reber et al., 1998). This finding has been replicated frequently (Brieber, Nadal, Leder, & Rosenberg, 2014; Forster, Fabi, & Leder, 2015; Forster, Leder, & Ansorge, 2012; Hamid, 1973) whereas there is little research on motion fluency. However, the findings in Experiment 1 and 3 clearly show that motion can be potent in biasing preference because a preference for the fluent associated stimuli was seen after one exposure. Similarly, after multiple exposures at the final rating, the preference was for the fluent associated stimuli and this finding was observed in Experiment 1 and replicated twice more in Experiments 3 and 5. It could be that stimuli associated with presentation time manipulations are easier to retrieve from memory, however, aside the experiments in this thesis, there is no current literature on this as the research highlighted above takes preference ratings on a trial-by-trial basis.

A second point to consider is the stimuli used during the rating blocks. Recall that in the motion fluency experiments, stimuli used in the experimental block in Chapters 2 and 3 rotated and increased/decreased in size and the static stimuli were rated in an upright orientation at the final size of the rotation. The stimuli viewed in the experiment is drastically different to the one participant rated at the end, whilst the shape and colours were identical, the stimuli in the experiment were viewed at a range of different and sizes and orientations throughout the rotation. The static visual of a single size and orientation of the stimuli could have provided a weak retrieval cue as it did not resemble the visual cue presented in the experiment. Similarly, the stimuli were also separated from the motion pair it was presented with in the experiment. In contrast, the stimuli rated in Chapters 4 and 5 were identical to the ones experienced in the experiment. In Experiments 6-8, participants interacted with the grape stimuli in the experimental block and an identical, single grape was presented in the rating block. Whilst this grape was static, in isolation, in the centre of the screen and void of the properties it possessed in the experiment (such as disappearing or paired with an inhibition signal) it was still the exact same visual cue participants were accustomed to. Similarly, in Experiment 9, although participants were tasting real-world drinks, the stimuli images were created by photographing the exact drinks that they would taste. By doing this, participants were exposed to an identical visual cue in the experiment that they would later encounter in the rating block. Therefore, the retrieval cues used in Chapters 4 and 5 might be stronger than those used in Chapters 2 and 3, explaining the contrasting results for a memory trace and transfer of the fluency affect to different contexts.

The final point to consider is whether pure perception is a weaker effect in general. As previously stated, there was no evidence that the fluency affects in Chapters 2 and 3 was able to generalise to a different context. The experiments in these chapters used a pure perception technique of perceptual motor fluency. This appears to be in contrast to Experiment 6 in Chapter 4 where the perception and inhibition button press task yielded a significant main effect of fluency. Although the statistics for the experiment are stronger, it appears that this main effect is driven by the significant difference between the fluent and disfluent associated grapes in the inhibition condition only. When looking at the pure perception condition, there was no significant difference between the fluent and disfluent associated grapes (t (39) = 1.59, p =.118, d =.252). A significant effect in the perception condition for the fluent in comparison with the disfluent associated grapes only emerges when perception is combined with action in Experiment 7. This finding of the sole perception condition yielding an insignificant result when rating a static version of the grape is consistent with the null results presented in Chapters 2 and 3. Comparing this to the inhibition condition, Experiment 6 and 7 both use inhibition as a single technique and both experiments show a significant preference for the fluent associated grapes in comparison to the disfluent associated grapes. Similarly, when comparing the Experiment 8 which combined perception, motor-action fluency and inhibition to the pure inhibition and perception + motor action fluency conditions in Experiment 7, there was no main effect of condition. This shows that pure inhibition alone was just as effective in biasing preference in the short-term.

Future research and final comments

The work in this thesis has provided the groundwork for preference bias research, using a short 3-minute game-like experiment on adults in the general population. Future research should focus on testing these implicit techniques on children. To start. I would replicate the immediate preference work tested in

Experiment 8 on primary school aged children with some key changes. In order to challenge the paradigm further, I would change the stimuli from grapes to foods that appear to be on polar opposite ends of the health spectrum. For example, the disfluent associated stimuli could be dried apple pieces which in the game would be packaged as crisps and the fluent associated stimuli would be an apple. This would be to ensure that I am not potentially promoting unhealthy foods should the paradigm be less potent in children than adults. Similarly, I would incorporate the 'real-world' element of Experiment 9 and instead of the on-screen rating style used in Experiment 8, at the end of the experiment the child would be asked to pick between a real version of the stimuli to take as a snack to eat. This preference rating further pushes the paradigm into the applied domain as the choice of which snack to take represents a very real decision that children make on a daily basis. If the game is able to bias the preference towards the fluent associated healthy food then measurable impacts can be seen.

The combination of mechanisms has implications for the greatest challenge for gamification approaches. That is, the challenge is for the processes/techniques used within the game environment to leave a trace in memory and shift behaviour and performance in the wider real-world context beyond the game. It is one thing to bias food preference in a child whilst playing a game, and quite another to bias choice towards healthier options at the dinner table at a later time. As noted in the introduction, inhibition training techniques do appear to have achieved this transfer from computer task to real-world food consumption, at least with long and repeated training sessions, as made clear in recent assessments of the applied implications of the research (e.g., Walker, Chambers, Veling & Lawrence, 2019).

Because I have now shown stable effects with very brief tasks, with few learning trials, I predict that repeated playing of the game resulting in spaced learning, could produce very stable effects when techniques are combined. For example, as well as the inhibition and speed of presentation utilized in this thesis, other perceptual properties could be implemented, such as contrast/salience (e.g., Reber et al, 1998; , Flavell et al., 2019; Dai, Cone & Moher, 2020), and smooth versus curved shapes (e.g., Bar & Neta, 2006, 2007), or symmetry (e.g., Makin, Pecchinenda & Bertimini, 2012). These techniques could be encountered independently and in combination as game players pursue goals such as gathering foods through various game levels.

Therefore, the approach I suggest is that, as well as the explicit inhibition training techniques focussed on overweight individuals engaged with dieting, a broader more implicit approach could also be taken. For example, the range of visuomotor techniques described in this thesis could be embedded within fun gaming environments, where there is no sense of overtly training, and as suggested here, often little awareness of game properties that affect preference. These approaches could be effective with particular target populations, such as obese adults, but also more generally as a means of broadly improving health and wellbeing in the general population. In particular, embedding preference nudges within existing fun game environments could be especially effective for children across a wide age range, and such early interventions might provide long-term dividends

It would be useful for these ideas to be considered in the future development of existing or new games to change behaviour. One approach could be to use converging methodologies where existing approaches based on social modelling such as the food dudes programme (Lowe & Horne, 2009; Lowe 2013; Upton, Upton & Taylor, 2013), could also utilize the basic visuomotor techniques discussed here in addition to the powerful techniques they already employ. Nudging behaviour simultaneously at these multiple levels could be more effective than any single approach. Therefore, further basic science examining individual mechanisms and the combination of techniques, to identify in controlled experimental conditions which may or may not shift preferences, could be a valuable research programme to provide the foundations from basic research to real-world impact on behaviour change via gamification.

Appendix A: Summary of children behaviour change games

Game type	Approach used	Behaviour change	Description	Results	Reference
Board game	Education / explicit	Healthy eating	‘Kaledo’ showed the players how much energy expenditure (exercise) they needed to burn off food from energy intake (consumption). For example, eating a banana gave you 10 points of energy intake and jumping on the spot gave you 8 points of energy expenditure. During the game, players were given a selection of physical activity and food cards with numbers on, as outlined above, with the goal being to ultimately be the winner who has the least difference between these two numbers.	Significant increase in the requisite knowledge in the treatment relative to control group. Similarly, there was a marked difference between the dietary intake of healthy foods between the two conditions, with the treatment group consuming one more portion of fruit or vegetables a day. There was no difference between the two conditions regarding either physical activity or BMI.	Amaro et al., (2006)
Video game	Explicit + social modelling	Healthy eating	‘Squires’ Quest’ attempted to increase the healthy eating habits of children. In this game children created a ‘squire’ avatar to look like them who was on a stoic quest for	Results of the initial study showed that although children increased their intake of fruit and vegetables by one serving per day the intervention did not achieve the	Baranowski et al., 2003

			knighthood. To achieve this, they had to overcome challenges, both in the game and real life. Challenges would include daily fruit and vegetable consumption goals, and recipes to make with their parents outside of the game. If players completed these challenges, they received a badge to level up their avatar, where upon their character would learn a new skill to use in the game (Protocol shown in Thompson et al., 2012).	goal of five daily portions. A follow up study found children who played the game picked healthy snack choices, but more research work was needed to see how the game impacted mealtimes	Follow up: Cullen et al., (2005) Further follow up: Thompson et al, (2012)
Mobile game	Education / explicit	Healthy eating	‘Time to eat’ mimicked commercially successful games such as Tamagotchi and Nintendo dogs by providing children with a virtual pet to look after. Children (age 13-15) would first select their pet and then name it, a deliberate step to induce a sense of ownership and connection. Children could then take photos of their food and submit them to the app where they would receive points for how much food they ate and how healthy the food was. A given pet’s emotional state was	Results of the pilot study showed that children who played the game ate a healthy breakfast 52% of the time, in comparison to 20% of the time for children who did not play	Pollak, Gay, Byrne, Wagner, Retelny & Humphreys, (2010)

			contingent on how many points the child had received, and if no food was logged a reminder would be sent to the child saying 'have you had breakfast? I'm hungry'.		
Video game	Explicit	Physical activity	Play, Mate! Can be applied to any game where a character / avatar is represented by quantifiable features (such as speed / time remaining). To motivate players to perform more physical activity, play mate gives in-game rewards for out-of-game physical activity levels. When applied to a game called 'Never ball', where players had to navigate a maze to collect coins, the more activity outside the game (as measured on a pedometer), the longer the player would get to collect coins in the game.	Players had a significant increase in physical activity levels when playing the game and significantly less sedentary time. Results also showed that players who had a lower gaming skill performed more physical activity than those with a higher gaming skill as they took advantage of the extra help in the game that more activity gave them.	(Berkovsky, Coombe, Freyne, Bhandari, & Baghaei, 2010)Berkovsky. Coombe, Freyne, Bhandari & Baghaei, (2010)
Video game	Explicit	Physical activity	Neat-O-Race is part of a package of virtual games where the player will wear a pedometer and pick an avatar in the game. When the player moves/walks/runs in real	Participants had a higher level of physical activity including high intensity physical activity when playing the Neat-O games packages.	Fujiki, Kazakos, Puri, Buddharaju

			life, the avatar will move around a racetrack. The player will play a race with other players and the person who moves most in the 24-hour period will win the virtual race. Players win activity points for the amount of physical activity they complete. These activity points can be exchanged for hints in other games on the Neat-O system such as Neat-O-Sudoku.		& Pavlidis, (2008)
Interactive board game	Explicit	Decrease neophobia / increase food pallet.	The subjects in this study were children with selecting eating habits and the parents had tried other behaviour change strategy without luck. Children were sat with a dietitian and had three categories of food for them to try (ready to try, maybe ready to try and not ready to try). The game consisted of boards with different coloured squares that coordinated with each food group, each square had a 'ready to try' and a 'maybe ready to try' food. The aim of the game was	At the beginning of the study, all children had unbalanced diets that did not consist of any fruits (expect for fruit juice) or vegetables. At the end of the study, all children had increased their repertoire of food and had a significantly more balanced diet. This finding was consistent at the 1-year post intervention time point.	Gillis, (2003)

			to roll the dice and move around the board. When the child landed on the square, if they ate the 'maybe' food, they got an extra roll and if they did not eat any of the foods, they moved back a place. If the child finished the game, they received a reward.		
Cooperative physical game	Cooperation	Increase physical activity	The 'game factory' program has a combination of cooperation physical activity games which require children to cooperate with one another to complete the game. The games are facilitated by teachers and use props to encourage teamwork. For example, the game 'islands' uses hula hoops and the children move around the hoops until the music stops. When the music stops the children are required to get into the hoops in groups of whatever number the teacher shouts.	After 6, fortnightly sessions, results showed that children engaged in significantly more pro-social behaviour in both the school and home environment.	Street, Hoppe, Kingsbury & Ma, (2004)

Story book game.	Competition	Increase vegetable consumption	FIT game used fictional superheroes (the FIT's) and the aim of the game was to help the FIT's capture the leaders of the Vegetation Annihilation Team (VAT). School children were competing with other schools to eat the most vegetables. If children met their target of vegetable intake, more of the story would be read out.	Amount of daily vegetables consumed significantly increased from 21.3g pre-test to 42.5 post-test. There was no increase in fruit consumption, however the game did not target fruit intake. There also was not a decrease in fruit consumption.	Joyner et al., (2017).
Trivia game	Explicit	Increase healthy eating	'Munch Crunch' is a health trivia game which is both educational and educational. It uses explicit teaching techniques and requires game users to answer questions about foods. The main aims of the game are to teach children about food information that will be remembered and used to make decisions when picking foods, to design a game that children will enjoy and want to play regularly which will encourage continuous use.	The game was tested on high school seniors and graduates, all of which said the game was fun and engaging. All participants increased their knowledge about food items from the game but no formal increase/decrease in healthy foods was monitored.	Mansour, Bhat, Yi-Luen Do (2009).

			An example of a trivia question in the game would be ‘which of the following does not provide your body with Vitamin D?’ a right answer increases points and a wrong answer decreases a team point.		
Physical game	Explicit / motivational	Increase healthy food intake	‘Sensing Fork’ was a device that children ate with during mealtimes. The fork detected eating behaviour (such as food choice and actions) which would be linked to a ‘hungry panda’ app on a phone. The app would provide playful feedback and persuade children to eat a variety of food. It aimed to resolve picky eating and to make children focus on eating the food rather than being distracted.	This game is a prototype and there are no testable measures to report	Kadomura et al., (2013).
Mobile game	Explicit	Diabetes management	This diabetes management game was developed to assist children in managing their health in a fun, interactive way. It used both intrinsic factors where children learned about the information of how to look after	This game is a prototype and there are no testable measures to report	Chomutare, Johansen, Arsand & Hartvigsen. (2016).

			their blood sugar levels and extrinsic factors where children were rewarded and were competing for motivation. The game was multicomponent with quizzes, daily diaries and a social network of other children with the same condition.		
Video game	Explicit knowledge based / social cognitive	Promote healthy behaviours	'Escape from Diab' and 'Nanoswarm: Invasion from Inner Space' are children's video games aimed to change children's diet, physical activity and adiposity. Each game consisted of 9 sessions with 40 minutes game play per session. This equated to approximately 6 hours in game play. Each session had a knowledge-based mini game which contained goal-directed behaviour to increase all of the core outcomes.	Outcomes that were measured were servings of fruit, vegetable and water intake and minutes of moderate/vigorous exercise. Results showed that children increased their fruit and vegetable intake by .67 servings per day and there was no effect on water intake or minutes exercised.	Baranowski et al., (2011). See Thompson et al., (2010) for further use of Escape from Diab.
Online game	Social modelling /	Increase fruit juice and	'Boy scout five-a-day badge' was an interactive video game that attempted to increase fruit juice and vegetable intake in	After the 9-week programme, fruit juice intake increased, as did the availability of fruit juice at home.	Thompson et al., (2009).

	explicit knowledge	low-fat fruit consumption	children. The aim of the game was to play with a boy scout avatar and overcome obstacles to eating more fruit and vegetables, such as not having enough time in the day or parents not having the vegetables to cook at home. The game required real life goal setting where the children would eat more vegetables and points were awarded for completion of goals.	Similarly, vegetable intake increased. These results were followed up at 6 months and had returned to baseline.	
Computer game	Explicit knowledge	Increase nutritional knowledge and improve eating habits	This game was played during school time for one hour, twice a week for a total of 10 hours play time. The game included educational quizzes and had multiple mini games built in. One of these mini games was called 'Store' which required children to classify foods into categories. A second game 'guess who' encouraged children to learn what each of the target foods contained by giving nutritional information about a hidden food and the child had to guess what the food	The target outcomes that were measured were nutritional knowledge of food items, dietary intake and eating habits. Results showed an increase in knowledge-based facts about food, a better-balanced diet and better eating habits as categorised through less snacking.	Turnin et al., (2001).

			was. In ‘guess who’ the foods were each given a different personality and personified as either a ‘good guy’ or ‘bad guy’		

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