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No priming in video games

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ABSTRACT

Video games depict a variety of different concepts. Models of learning in games like the GLM (General Learning Model) and GAM (General Aggression Model) predict that exposing players to these in-game concepts can lead to important changes in player behaviour.

Priming effects are thought to be key to determining these changes in behaviour. However, recent research has suggested problems with the priming effects that have previously been observed in the video game literature. Indeed, widespread methodological issues with this body of research make it unclear whether priming effects occur at all in video games.

Two experiments (total $N = 532$) investigated whether priming effects still occurred in video games when known confounds in the literature were accounted for. Priming was observed in neither study. However, in both studies a novel negative priming effect was observed instead, in which exposure to a specific concept inhibited players' reactions to things that were related to that concept.

These studies support previous research which indicates there may be serious confounding in the video game literature. They also suggest that the priming-related effects of video games may be over-estimated. Finally, they highlight the potential existence of negative priming as an effect of video game play.

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1. Introduction

Video games are an extraordinarily popular form of entertainment. At the time of writing this, *Minecraft* has sold over 100 million copies (Rad, 2016); *Grand Theft Auto V* over 65 million (Makuch, 2016), and *Tetris* has enjoyed over 400 million paid downloads (Reilly, 2016). These games depict a diversity of different concepts and experiences. *Call of Duty 3* features the sounds and sights of World War II Normandy. In *Papers, Please*, players are shown the necessary evils of being a border guard in a fictional dystopian society. *That Dragon, Cancer* depicts what it is like to care for a terminally ill child. *Desert Strike* presents the player with Apache helicopters that are raining death on ground forces.

Given their ubiquitous nature and varied content, it is unsurprising that there has been considerable interest in what the effects of video games might be on their players. In recent years, explanations of these potential effects have emerged which centre around the idea that playing games which feature specific concepts

leads to the priming of these same concepts, and hence important changes in player behaviour.

One prominent model of how playing games can lead players to express a variety of new behaviours through mechanisms of priming is the GLM, or General Learning Model. Under the GLM, when players observe the depiction of a concept in a game, reactions to that same concept becomes temporarily facilitated, or primed (Sternberg, 2005). This effect is theorised to lead to short-term changes in player behaviour in a variety of ways. For instance, the priming of a concept is predicted to make scripts associated with the primed concept easier to activate, and hence more likely to be used. Furthermore, priming is posited by the GLM as an important step in determining longer-term changes in behaviour. As exposure to specific in-game concepts is repeated over longer periods of play, priming effects are reinforced, and temporary effects on player behaviour are made chronic (Buckley & Anderson, 2006).

The path to behavioural change outlined above relies on the idea that the concepts which are depicted in games are primed by these games. However, crucially, it is no longer clear why, or if, priming actually *happens* in video games. Numerous studies over the past two decades have seemingly provided conclusive evidence that playing games leads to the priming of the concepts that are

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depicted in these games (e.g. (Anderson et al., 2004; Greitemeyer & Osswald, 2011)). However, recent research has challenged both the validity of these experiments and the generalizability of the priming effects which they demonstrate.

The key reason why these effects have been called into question is to do with experimental control. As Adachi and Willoughby (2011) note, many experimental studies in the literature use an approach in which different games are used as different experimental conditions. Whilst these games may differ greatly in terms of the content which they contain, they also differ in other ways. As a consequence, it is unclear whether any observed difference in priming is due to the content of the games under test, or whether it may instead be due to the influence of some third factor.

The experiments reported here therefore investigate whether priming effects occur in video games when potential sources of variation between experimental conditions are removed from experimental designs.

In Experiment 1, two versions of a bespoke maze game were made. This game was reskinned so that it formed two different conditions. In one condition, the game was vehicle-themed. Players took on the role of a car looking for a garage whilst avoiding trucks. In the other condition, the game was instead animal-themed. Players took on the role of a mouse looking for their mouse hole whilst avoiding cats. After play, participants engaged in an image categorisation task featuring in-game concepts. The aim of this study was to determine whether a game featuring specific concepts lead to those concepts being primed by play. If this was the case, then the concept of the vehicle-themed game would have the concept of 'vehicles' primed, whilst the players of the animal-themed game would have the concept of 'animals' primed.

Following this study, a second experiment was conducted. The aim of this study was to replicate the effects observed in Experiment 1, and also to discover if priming occurs if people only play a game for a short period of time. In Experiment 2, a bespoke game was again custom made. In this case, the game was a vehicle-themed infinite runner game. However, due to the small effect sizes observed in previous experiments this experiment was run online in order to obtain a large sample size ($n = 460$). Participants again engaged in an image categorisation task after play.

Results of both experiments not only indicated an absence of priming, but instead showed a negative priming effect in which participants were slower at categorising the content of the games that they played.

2. Background

2.1. The importance of priming effects in video games

The GLM, or General Learning Model (Buckley & Anderson, 2006) describes how exposure to games may lead to changes in player behaviour. Under the GLM, when players are exposed to depictions of specific concepts in a game, these concepts become temporarily easier for those players to access again. This priming then spreads to related knowledge structures such as scripts, schema, and beliefs. This leads to players being temporarily more likely to express behaviours which are related to the concepts present in the games that they have been playing. For instance, playing a prosocial game is thought to prime prosocial concepts, and lead temporarily to players expressing prosocial behaviours (Greitemeyer & Osswald, 2011). Similarly, playing a game which contains a depiction of sexual behaviour might prime sexual concepts (Yao, Mahood, & Linz, 2009), and playing a game which contains a depiction of aggression might prime aggressive concepts (Anderson et al., 2004).

As well as these short term effects, the GLM argues that playing

games can lead to long-term changes in personality through processes of reinforcement. Reinforcement refers to the idea that repeatedly priming a concept or knowledge structure will lead to that same concept or knowledge structure becoming easier to activate again, not over short periods of time, but over long periods of time. Knowledge structures which may become reinforced under the GLM include beliefs and attitudes related to in-game content, perceptual and expectation schemata, and behavioural scripts (Buckley & Anderson, 2006).

It is important to note that the GLM is itself an extension of an earlier, extremely influential, theory of how the aggression-related content of video games leads to aggressive behaviour. This narrower model is known as the GAM, or General Aggression Model (Anderson & Bushman, 2002). Just as priming is key to the GLM, the idea of "priming effects" (Bushman & Anderson, 2001) are similarly integral to this model. Under the GAM, when players are exposed to depictions of aggression in video games, concepts which are related to aggression are primed. These concepts include both objects which may be depicted in a game (such as a gun), and more abstract things (such as the idea of 'harm' or 'kill' (Anderson & Carnagey, 2004)). And just as in the GLM, this priming may then spread to related knowledge structures and lead to both short term changes in behaviour, as well as long term changes in behaviour through processes of reinforcement (Anderson & Carnagey, 2004).

Priming is therefore a theoretical important effect when it comes to learning and behaviour change in games. Furthermore, there are diverse examples of priming's seeming existence in video games. For instance, in the studies outlined above, Yao et al. (2009) tested whether playing games which feature sexual content leads to the priming of sex-related concepts. In this study, participants played either a game with sexual content (*Leisure Suit Larry: Magna cum Laude*), or a game which did not feature sexual content (*The Sims II* or *PacMan II*). Researchers found that playing the game with sexual content caused the priming of sexual concepts. The researchers theorised that this effect may help explain the existence of sexually objectifying behaviours amongst some groups of gamers. Similarly, Greitemeyer and Osswald (2011) investigated whether playing games which depict prosocial behaviour leads to the priming of prosocial concepts, and hence prosocial behaviour. Players were assigned to play either a game with prosocial content (*Lemmings*, in which the player must attempt to stop the titular characters from plummeting to their doom), or a game which did not have prosocial content (*Tetris*, in which players stack blocks). Researchers found playing the prosocial game led to greater "accessibility of prosocial thoughts". This priming effect was linked to greater amounts of prosocial behaviours being expressed by players immediately following play. For instance, players of prosocial games were more likely to pick up pencils spilled by a confederate in the laboratory, and likely to agree to take part in future research with no compensation, and more likely to help a harassed experimenter.

Finally, a variety of studies have tested whether playing games which feature depictions of aggression leads to the priming of aggression-related concepts. For example, in (Anderson et al., 2004) participants were exposed to either a game which featured a depiction of violence (*Marathon 2*) or a game which did not (*Glider Pro*). Results indicated that playing *Marathon 2* rather than *Glider Pro* resulted in the priming of aggression-related concepts. This kind of effect is commonly used to support the arguments of academics who suggest that playing video games may lead to players behaving more aggressively. These predicted aggressive behaviours range from attempting to inflict more discomfort on individuals in lab based tasks such as the Competitive Reaction Time Task (e.g. (Anderson & Carnagey, 2009)), to increases in committing real-world acts of violence (e.g. (Anderson et al., 2008)).

2.2. Evidence against priming effects in video games

However, despite this evidence, accusations of confounding in the literature muddy the picture of how priming might function in games. Numerous studies may have seemingly demonstrated that playing games leads to the priming of the concepts that are depicted in these games. However, recent research has challenged both the validity of experiments like these and the generalizability of the effects which they demonstrate.

As noted in (Adachi & Willoughby, 2011), experimental research into the effects of games is often conducted using a setup in which each experimental condition is represented by a different commercial off the shelf (COTS) video game. An issue with this methodology, in which experiments are conducted “between video games” (Barlett, Harris, & Baldassarro, 2007), is that it may lead to false positives. As (Valadez & Ferguson, 2012) put it, “the first limitation with experimental research [into the effects of video games] is the failure of many studies to adequately equate video game conditions on confounding variables such as competitiveness, difficulty, and pace of action”.

Recent findings seem to support the severity of this issue, as previously robust-seeming findings prove difficult to replicate under more controlled experimental setups. For example (Charles, Baker, Hartman, Easton, & Kreuzberger, 2013), failed to observe a significant effect on any measure of aggression or aggressive thoughts between groups of participants who played either a violent or a non-violent game, leading them to suggest that “the established effect [of VVGs on aggression] is far more fickle than most admit”. Similarly, in (Tear & Nielsen, 2014), the authors investigated the effect of playing either a non-violent video game, a violent video game, or an ultra-violent video game. No effects on prosocial behaviour were observed – even for those participants who played the ultra-violent video game. In the same vein, (Kneer, Elson, & Knapp, 2016), attempted to discover whether it is the aggression-related content of games that leads to the priming of aggression-related concepts after play at all, or whether this effect may be the confounded product of “the third variable – game difficulty” (Kneer et al., 2016). Rather than use two different games, they instead manipulated the game *Team Fortress 2* to form different conditions. In some conditions, players burned each other to death by shooting flamethrowers at each other, whilst in others they were instead equipped with devices which “exhausted rainbows ... [which] incapacitated characters by making them drop to the ground convulsing with laughter” (Kneer et al., 2016). In other words, one condition contained aggression-related content, whilst the other did not. Additionally, conditions were formed in which the game was either more or less difficult. Experimental results not only yielded a null effect for aggressive or non-aggressive conditions, but additionally revealed that the difficulty of the game had a significant effect on the priming of aggression-related concepts.

It would seem that in the words of one media effects scholar, at least when it comes to the priming effects of video games, “overall, making clear, declarative statements from this body of work is difficult.” (Ferguson, 2015).

2.3. Measuring priming

Several tasks are commonly used to measure priming effects using a variety of different stimuli. For instance, image categorisation tasks measures the priming of concepts by looking at how quickly individuals are able to categorise images as belonging to one category as opposed to another. In this task participants are shown a sequence of pictures and are asked to sort these pictures into different pre-specified categories as quickly as possible. This categorisation is usually done by having participants press specific

buttons, though sometimes participants are told to verbalise the name of the relevant category (e.g (Tipper & Driver, 1988)). This task is commonly used to investigate priming effects in the cognitive psychology literature (e.g (Lloyd-Jones & Humphreys, 1997; Martinović, Gruber, & Müller, 2009)).

Conversely, Lexical Decision Tasks (LDTs) measure the priming of concepts by looking at how quickly individuals are able to categorise words. In an LDT, participants are presented with a series of letter strings on a computer monitor. These strings can either be words (e.g. ‘soldier’) or non-words (e.g. ‘slodier’). Non-words may either be random letter strings (e.g (Smeesters, Mandel, & article., 2006)), or anagrams formed by partially scrambling words used elsewhere in the LDT (e.g (Pichon, Boccato, & Saroglou, 2007)). Participants are told that they must categorise each string as either a word or a non-word as quickly as possible by pressing a button. The theory goes that if a concept is primed, then reactions to strings which are related to that concept will be speeded up. Therefore, the priming of a concept can be measured by seeing how quickly participants make decisions about strings which are related to that concept (Koriat, 1981).

Similarly, word fragment completion tasks such as the instrument used in (Carnagey & Anderson, 2005) measure the priming of concepts by looking at how likely participants are to categorise words in a certain way. Word fragment completion tasks involve participants ‘filling in the gaps’ in a series of words which have letters missing. These fragments can typically be turned into words which are related to several different concepts (e.g. ‘K I _ _’ can become either ‘KISS’ or ‘KILL’), and the proportion of fragments which a participant turns into words that are related to a given concept is used to measure the priming of that concept.

2.3.1. Measuring priming via interaction effects

As a final point when it comes to measuring priming, it is important to note that priming is frequently tested by looking for an interaction between two different factors. In this analysis, experimental manipulations are treated as between-participants factors whilst a participant’s responses or reaction times to either target-related or target-unrelated stimuli are treated as two levels of a within-participants factor. Priming is tested for by looking for a significant interaction between these factors (e.g (Holland, Hendriks, & Aarts, 2005; Kunda, Davies, Adams, & Spencer, 2002; Pichon et al., 2007)).

Researchers do not generally explain *why* statistics are conducted like this. However, one rationale is that a participant’s reaction time to target-related stimuli may be influenced by both the priming of a specific concept, and also that participant’s reaction time to stimuli *in general*, leading to a ‘false positive’. For instance, in (Bushman, 1998), researchers were interested in whether violent videos primed violence-related concepts. Participants were exposed either to a violent video, or a non-violent video. If priming was measured solely through recording reactions to the target concept of violence, the physiological effects of a more arousing video on reaction times to *all* stimuli could potentially lead to the false identification of a conceptual priming effect. In this case, as in others, the priming measure therefore contained stimuli which were related to the target concept of violence (e.g. the word ‘punch’) and stimuli which were not related to it (e.g. the word ‘snail’). The priming effects of violent videos were then tested via a $2 \times 2 \times 2$ ANOVA, with videotape type (violent or non-violent) and sex (male, female) as between-participants factors and word type (violence-related, violence-unrelated) as a within-participants factor. A significant interaction between videotape type and word type was observed, suggesting to the researchers that violent videos primed to violence-related concepts.

2.4. Negative priming

As Versace and Allain (2001) point out, “The priming paradigm is not always characterized by facilitating phenomena; in many experiments, it has also revealed inhibitory effects”. When concepts are processed by an individual, priming effects occur in which reactions to related concepts are made easier (facilitated). Conversely, when an individual ignores a concept, a mirror-image effect occurs in which that individual’s reactions to related concepts are made more difficult (inhibited). This inhibition after ignoring is referred to as “negative priming” (Tipper, 2001).

Negative priming effects have repeatedly been demonstrated in the cognitive psychology literature. For instance, Tipper (1985) showed participants a series of images of two different concepts which were superimposed on each other. Participants were asked to name only one image, whilst ignoring the other. Those who had previously ignored a concept (e.g. ‘cat’) were slower at subsequently naming a related concept (e.g. ‘dog’). Similarly, in (Chiappe & MacLeod, 1995), researchers demonstrated that ignoring the presentation of a word (e.g. ‘banjo’) made categorization decisions on a related word (e.g. ‘fiddle’) slower.

As outlined above, negative priming is observed when people ignore specific information. This has led to this effect’s utilisation in experiments that investigate the circumstances which cause people to ignore specific pieces of information. For instance, Goeleven, De Raedt, Baert, and Koster (2006) tested for a negative priming effect in order to find out whether individuals with depression were less able to ignore sadness-related information than individuals without depression. They found that this was, indeed, the case.

It is important to note that image categorisation tasks are commonly used for measuring negative priming effects. For instance, in (Tipper & Driver, 1988), researchers wanted to find out whether ignoring a concept led to the negative priming of related concepts. They therefore repeatedly asked participants to ignore a picture of some concept (for instance, a cat), and then had them categorise a picture of something from the same category (for instance, a dog). Results indicated that ignoring a concept negatively primed categorisation decisions about things from the same category. Similarly, when (Ballesteros & Mayas, 2015) investigated the effects of ageing on negative priming, they first instructed participants to ignore a series of images, and then tested for negative priming by having them categorise the previously-ignored items as either artificial or natural. In a related vein (Buchner, Zabal, & Mayr, 2003), used an image categorisation task to investigate the negative priming effects of auditory distractors. Participants were played either animal-related or instrument-related sounds, and asked to categorise a series of pictures as either animals or instruments. Being exposed to conceptually irrelevant sounds led to the negative priming of categorisation decisions.

3. Experiment 1: priming and negative priming in a maze game

3.1. Introduction

In order to investigate whether priming still occurs in video games when potentially confounding differences between experimental conditions are controlled we had participants play a maze game. In order to avoid confounds, experimental conditions were formed by reskinning this single game so that two different versions of it were created which were identical in every way except for the concepts that they depicted. One game featured an animal-related theme, whilst the other had a vehicle-related theme. After play, participants were tested for the priming of these concepts via an image categorisation task. If the content of video games primes

their players, then playing an animal-themed game should prime the concept ‘animals’, whilst playing a vehicle-themed game should prime the concept of ‘vehicles’.

3.2. Method

3.2.1. Aim

This experiment aimed to investigate whether the priming effects seen in the video game literature remain when known confounds are removed from an experimental design.

3.2.2. Hypothesis

The literature predicts that priming happens in video games. Or, more formally:

H1. Reaction times to animal-related images on an image categorisation task will be speeded for people who play an animal-themed game, whilst reaction times to vehicle-related images on an image categorisation task will be speeded for people who play a vehicle-themed game.

3.2.3. Design

The experiment had a 2 (game theme) x 2 (image type) mixed design. Participants played either an animal-themed maze game, or a vehicle-themed maze game. Each participant was then tested for their reaction times to both animal-related and vehicle-related images on an image categorisation task.

3.2.4. Games

Maze-based video games have remained popular for over 40 years (e.g. (Pac-Man Championship Edition, 2007; Spelunky, 2008; The Amazing Maze Game, 1976; The Last Guy, 2008)). The maze game used in this experiment was played from a top-down perspective. Players controlled an avatar which was trapped in a labyrinth of tight and twisting passages. Whilst moving through this maze, the player had to avoid moving obstacles whilst picking up bonuses and attempting to find an exit point. This search, avoidance, and bonus-collecting continued for 200 s, after which the game ended. Despite the players being told to look for an exit, in order to ensure that all players played the game for the same length of time, no exit was included in the maze.

Whilst the rules of the game were identical in both conditions, the concepts depicted in each game varied. In the vehicle-themed condition, the player took on the role of a car, avoided trucks, and collected tyres while looking for a garage. In the animal-themed condition, the player took on the role of a mouse, avoided cats, and collected cheese whilst looking for a mouse-hole. Both games are displayed in contrast to each other below as Figs. 1 and 2.



Fig. 1. The animal-themed maze game.

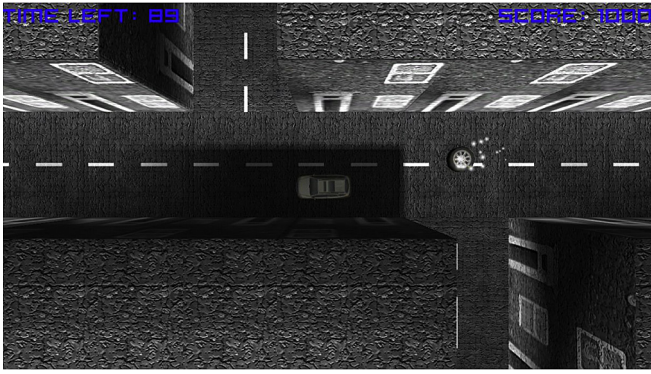


Fig. 2. The vehicle-themed maze game.

3.2.5. Measures

An image categorisation task was used to measure the priming of both animal-related and vehicle-related concepts. In this task, participants were repeatedly shown images of either vehicles (e.g. a train) or animals (e.g. a dog). They were then asked to categorise these images as belonging to either vehicles or animals by pressing either the left or right arrow keys (see Fig. 3 below). The speed with which participants categorised animal-related images was used as a measure of their priming of animal-related concepts. The speed with which participants categorised vehicle-related images was used as a measure of their priming of vehicle-related concepts. The specific images which were used in this task were taken from (Rossion & Pourtois, 2004).

The reaction times of each participant to vehicle-related images was used to measure their priming of vehicle-related concepts. The reaction times of each participant to animal-related images was used to measure their priming of animal-related concepts. In order to do this, following eight training trials, each participant's correct reaction times to both animal-related images and vehicle-related images were recorded separately.

In line with recommendations within the literature (e.g. (Whelan, 2008)), in order to mitigate the effects of the “long spurious reaction times” (Ratcliff, 1993) which are frequently found in reaction time data, reaction times were log-transformed prior to analysis, a technique which is “commonly employed” (Fazio, 1990) to minimise the impact of outliers and maximise the power of studies which use reaction time data.

3.2.6. Participants

74 native English speakers took part in the experiment. Participants were randomly assigned to experimental conditions, with 37 playing the game which featured animal-themed concepts and 37 playing the game which featured animal-themed concepts. 46 of the participants were aged 18–24, 15 were aged 25–29, 11 were aged 30–34, and the remaining 2 were aged 35 or older. 32 participants were female, and 42 participants were male. Participants



Fig. 3. An image categorisation task trial.

were recruited from within a University library, and were offered a bar of chocolate in exchange for taking part in the experiment.

3.2.7. Procedure

After agreeing to take part in the experiment, participants were given an informed consent sheet. Participants were then guided to a desk with a computer and informed that the experimenter would not talk to them for the rest of the experiment unless absolutely necessary. The screen in front of them showed them a set of instructions for how to play the maze game. As with the previous experiment, these instructions did not mention any words related to the theme of the game that was being played. Instead, they used images to show participants how to play the game (see Fig. 4 below) (see Fig. 5).

After reading the game's instructions and indicating that they wanted to continue, participants were then exposed to either the animal-themed maze game or the vehicle-themed maze game. In order to engage participants with the game, they were told in the instructions to try to find an exit before a timer ran out. After 200 s of play, the game ended and a screen informed the participant that another task was about to begin. Participants were informed by the screen to move to an adjoining computer, where the image categorisation task was set up and ready to begin. Participants were given on-screen instructions detailing how to complete this task. Following completion of this task, participants were fully debriefed by the experimenter.

3.3. Results

Means and standard deviations for each treatment are presented below. These statistics are based on the log-transformed reaction times of participants (see Tables 1 and 2).

The effects of game theme (animal-themed, vehicle-themed) on reaction times to animal and vehicle-related images was tested via a 2×2 mixed-design ANOVA, with game theme as a between-participants factor and image type as a within-participants factor. Results indicated that there was a statistically significant main effect for image type, $F(1,72) = 39.489$, $p < 0.001$, $\eta^2 = 0.338$. There was no statistically significant effect for game theme, $F(1,72) = 0.012$, $p = 0.914$, $\eta^2 = 0.0001$. There was a statistically significant interaction effect between game theme and word type, $F(1,72) = 5.014$, $p = 0.028$, $\eta^2 = 0.043$. A line graph showing these effects is presented below as Fig. 6.



Fig. 4. Instructions for the vehicle-themed game.

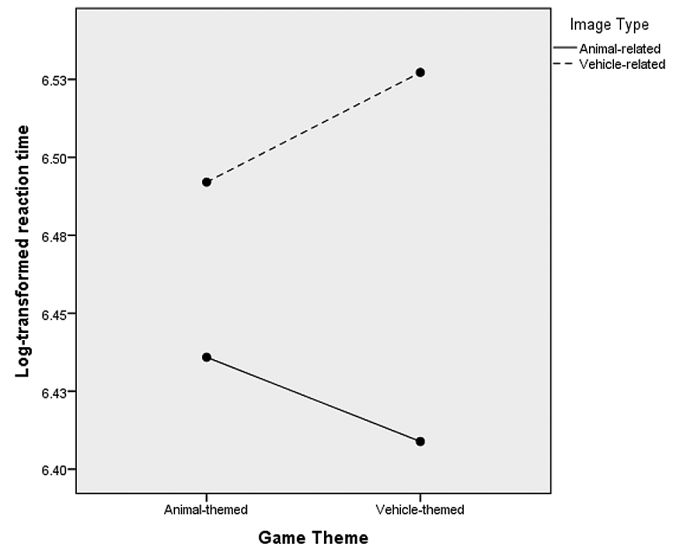
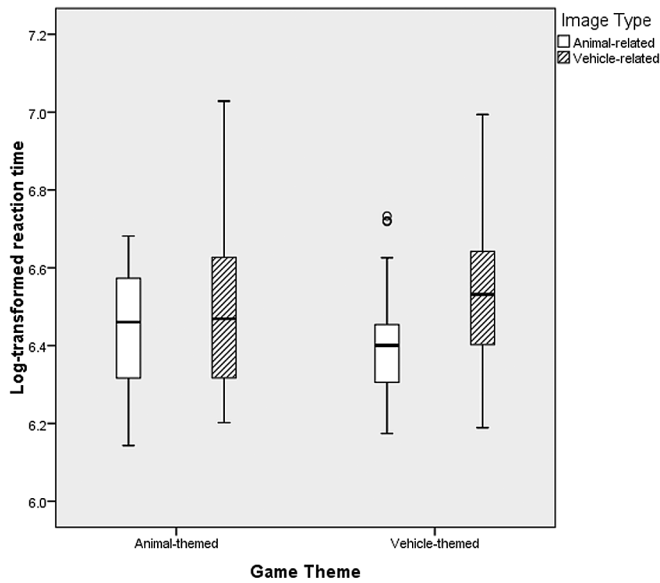


Fig. 5. Box-plot of reaction times to animal-related and vehicle-related images, split by condition.

Fig. 6. Line graph showing the interaction between image type and game theme.

Table 1

Means and standard deviations of reaction times to images for players of animal-themed and vehicle-themed games. Standard deviations in brackets.

Game Theme	Image Type	Reaction Time	N.
Animal-themed	Animal-related	6.43 (0.15)	37
	Vehicle-related	6.49 (0.21)	37
	Total	6.46 (0.18)	37
Vehicle-themed	Animal-related	6.41 (0.15)	37
	Vehicle-related	6.52 (0.19)	37
	Total	6.47 (0.17)	37
Total	Animal-related	6.42 (0.15)	74
	Vehicle-related	6.50 (0.20)	74
	Total	6.46 (0.17)	74

Table 2

Means and standard deviations of reaction times to images for players of the infinite runner game, split by length of play. Standard deviations in brackets.

Length of Play	Image Type	Reaction Time	N.
Control	Animal-related	6.491 (0.263)	169
	Vehicle-related	6.473 (0.251)	169
	Total	6.482 (0.257)	169
20 Seconds	Animal-related	6.399 (0.165)	142
	Vehicle-related	6.430 (0.183)	142
	Total	6.414 (0.174)	142
120 Seconds	Animal-related	6.420 (0.197)	149
	Vehicle-related	6.427 (0.179)	149
	Total	6.423 (0.188)	149
Total	Animal-related	6.440 (0.219)	460
	Vehicle-related	6.445 (0.210)	460
	Total	6.443 (0.215)	460

3.4. Discussion

This experiment suggests that playing video games does not lead to priming. Players of the animal-themed games were not faster at categorising animal-related images, whilst players of the vehicle-themed game were not faster at categorising vehicle-related images.

However, in addition to this, the results of this experiment suggest that playing video games can lead to *negative* priming. As

seen in Fig. 6, a significant interaction occurred between image type and game theme. Players of the animal-themed game were slower at reacting to images of animals (–6.43 vs. 6.41), whilst players of the vehicle-themed game were slower at reacting to images of vehicles (6.52 vs 6.49).

It is important to point out that the small sample size used in this experiment ($n = 74$) does not affect the trustworthiness of this result. Small sample sizes can lead to Type II errors: Mistakenly ‘missing’ significant results. However, it is important to point out that small sample sizes cannot cause Type I errors – the incorrect rejection of a null hypothesis, or a ‘false positive’. Since we *did* observe significant (rather than null) effects in this study, Type I errors are out of the question. Therefore, the study’s sample size should not impact the trustworthiness of these results.

It is interesting that we obtained such a clear indication of negative priming in this experiment. This result might be due to the experiment’s design. After all, whilst this effect has not previously been observed in the literature, no study in which priming was observed has controlled variation between experimental conditions in a similar way to the method that was used here. Supporting this idea is the effect size observed in this experiment. The negative priming effect observed in this study is small, ($\eta^2 = 0.043$). In other words, less than 5% of the observed variance in reaction times in this study could be chalked up to negative priming. This makes it seem likely that detecting this effect may *require* the kind of tight experimental control that was used here – after all, if other factors differ between experimental conditions, noise from this uncontrolled variation may swamp a small negative priming effect and effectively render it invisible.

As outlined in Section 3.2, the stimulus materials used in Experiment 1 are tightly controlled, differing only in their theme: the presentation of either animals or vehicles. However, this design is not without its limitations. For example, it can be argued that being exposed to animals (rather than vehicles) in a game may lead to a host of different psychological effects which might then indirectly lead to the observed negative priming effect. For instance, playing a mouse which is being chased by a cat might be more engaging or exciting; playing a vehicle might lead to a slower pace of game. Experiment 2, detailed below, addresses directly this limitation of the study and further severely tests the idea that depicting a concept in a video game leads to that concept being primed.

A final point to highlight when discussing the results of this study is the population of participants which were used in this experiment. Participants in this study were not necessarily frequent gamers – they were a group of participants recruited from within a University environment, regardless of whether they played games frequently or not. However, the most important population when it comes to understanding the effects of video games is a specific group: people who play games frequently. This limitation of the experiment under discussion here is addressed in Experiment 2. In the experiment below, participants were recruited online, via large game-playing portal websites. This resulted in the population for Study 2 generalising well to gamers as a group, with the vast majority of participants playing video games on a frequent basis.

4. Experiment 2: priming and negative priming at short exposures

4.1. Introduction

The previous experiment paints a vivid picture of what priming might look like in video games when confounds are removed from experimental designs. Not only does it suggest that priming does not happen when people play video games, but it even seems to suggest that negative priming may instead occur.

However, precisely *when* this negative priming might occur during play is unclear. It might be the case that negative priming occurs almost immediately during play. On the other hand, this effect may only occur after players have been exposed to a game for a longer period of time.

This question has important consequences for understanding how games might affect their players. If it takes longer periods of time for negative priming to set in, players might still spend a substantial amount of time at the beginning of their play sessions being primed by in-game concepts. This would support the proposed effects of models which rely on the priming of concepts during play. However, if players are very quickly negatively primed by the content of a game, then route to behaviour change would seem less likely.

Finally, it is important to note that whilst the games used in the previous experiment were functionally identical in every way, their rules allowed their players latitude in how they played in each condition. For instance, players in the vehicle-themed game might obey the rules of the road, whilst players in the animal-themed game might try to run away from in-game enemies. Similarly, as outlined in the discussion of the previous experiment, the presentation of one set of concepts or another may lead to psychological effects other than priming. In order to determine whether the effects seen in the previous experiment remain when no such effects are possible, in this experiment we did not use as stimulus materials a single game which was reskinned to present two sets of concepts. Instead we used a single game, which was played for varying lengths of time, with priming (or negative priming) measured after these different time periods. Additionally, in order to determine whether the effects seen in the previous experiment generalise to other kinds of game, a different genre was used in this experiment: the infinite runner. This is described in more detail in Section 4.2.5 below. A final limitation of the research outlined as Experiment 1 is its generalizability to gamers as a group. In order to address this limitation, a more representative sample of gamers is needed.

In order to investigate these issues, this experiment was conducted online. Participants were recruited via gaming portal websites and social media, encouraging the recruitment of a more representative sample of gamers. We either placed these

participants in a 'control' condition in which they had all measurements taken before playing a game at all, or had them play an online vehicle-themed infinite runner game for either 20 or 120 s before testing them for priming via the image categorisation task used in the previous study. How priming changed over time could therefore be determined by comparing reaction times between lengths of exposure (i.e. control vs. 20 s vs. 120 s). If negative priming occurred immediately, then there should be a significant interaction effect between measurements taken in the control condition and at 20 s. Conversely, if negative priming takes longer to set in, then this effect should instead be seen between 20 and 120 s.

4.2. Method

4.2.1. Aim

This experiment aims to investigate whether priming or negative priming happen after very short exposures to video games.

4.2.2. Hypothesis

H1. Negative priming sets in early into play. Therefore, playing a vehicle-related infinite runner game for 20 s will cause negative priming - the slowing of reactions to vehicle-related images in comparison to animal-related images.

H2. Negative priming begins later during play. Therefore, playing a vehicle-related infinite runner game for 120 s will cause negative priming - the slowing of reactions to vehicle-related images in comparison to animal-related images.

4.2.3. Design

The experiment had a 3 (length of play) x 2 (image type) mixed design. One group of participants had their reaction times measured before playing a vehicle-themed infinite runner game, and acted as the control. A second group of participants had their reaction times measured after 20 s of play. A third group had their reaction times measured after 120 s of play. Reaction times were measured to both vehicle-related and animal-related concepts. These were transformed by taking the natural logarithm of reaction times, as in the previous experiment.

4.2.4. Measures

An image categorisation task was again used to measure the priming of both animal-related and vehicle-related concepts. The reaction times of each participant to vehicle-related images was used to measure their priming of vehicle-related concepts. Since there was only a single target in this measurement procedure, a set of animal-related and vehicle-related images were produced, and the reaction times of each participant to animal-related images was used as a control. This use of target-unrelated stimuli as a statistical control is commonly employed in the priming literature (e.g. (Holland et al., 2005; Kunda et al., 2002; Pichon et al., 2007)). – see Section 2.3.1).

In order to do this, following eight training trials, each participant's correct reaction times to both animal-related images and vehicle-related images were recorded separately. Reaction times were also log-transformed in the same fashion as in previous experiments.

It is important to also point out that due to the use of multiple (2) comparisons in this experiment, Bonferroni corrections were used to avoid a risk of false positives. Thus, in this experiment $\alpha = 0.025$.

4.2.5. Games

The infinite runner game used in this experiment reproduced the gameplay of popular games like *Temple Run*, but using a car-based theme. Participants took on the role of a small SUV, driving into increasingly dense traffic. In order to survive, the participant had to quickly anticipate where to place himself on the road, and switch lanes accordingly. This was done with the left and right arrows. The game is shown below as Figs. 7–9.

4.2.6. Participants

This experiment took place online. The infinite runner was placed online on popular video game portal websites (i.e. kongregate.com, newgrounds.com). Participants were recruited both through the portal itself (i.e. they were browsing on one of these portals and took part out of interest) and via social media (i.e. we set up a Facebook page for the game and encouraged participants to share it with their friends via social media).

460 native English speakers took part in the experiment. 342 participants were men, 101 were women, 9 identified themselves as ‘Other’, whilst 8 preferred not to state their gender. The majority (267) of these participants were frequent gamers, playing at least once a day. A further 121 played at least once a week. 36 preferred not to answer the question, whilst the remaining 36 participants played once a month or less. 282 of the participants were aged 18–24, 98 were aged 25–29, 64 were aged 30–34, and the remaining 16 were aged 35 or older.

Participants were randomly assigned to experimental conditions, with 169 taking the image categorisation task before playing the game, 142 taking it after playing the game for 20 s, and 149 taking the image categorisation task after playing for 120 s.

4.2.7. Online experimentation

This experiment is run online. Running an experiment online rather than in the laboratory is appealing for many reasons. Firstly, whilst laboratory samples are limited to the specific people whom an experimenter can physically get into their laboratory, conducting a study over the internet gives an experimenter access to many thousands of potential participants. Additionally, conducting an experiment over the internet gives experimenters access to several mechanisms to recruit these participants with. These avenues for online participant recruitment include both newsgroups, portal sites, forums and social media (Hooley, Wellens, & Marriott, 2012), as well as newer micro-work platforms such as Amazon Mechanical Turk (“Amazon Mechanical Turk - Welcome,” n. d.) and Crowdfunder (“Make your data useful,” n. d.).

In addition to this advantage when it comes to quantities of participants, some argue that there are also advantages to the quality of participants who may be recruited online. Researchers



Fig. 7. Vehicle-themed infinite runner game.

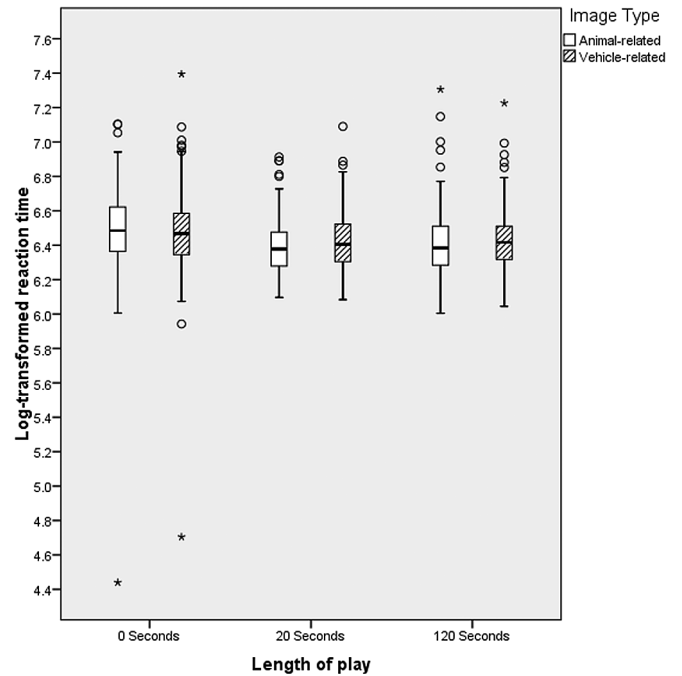


Fig. 8. Box-plot of reaction times to animal-related and vehicle-related images, split by length of play.

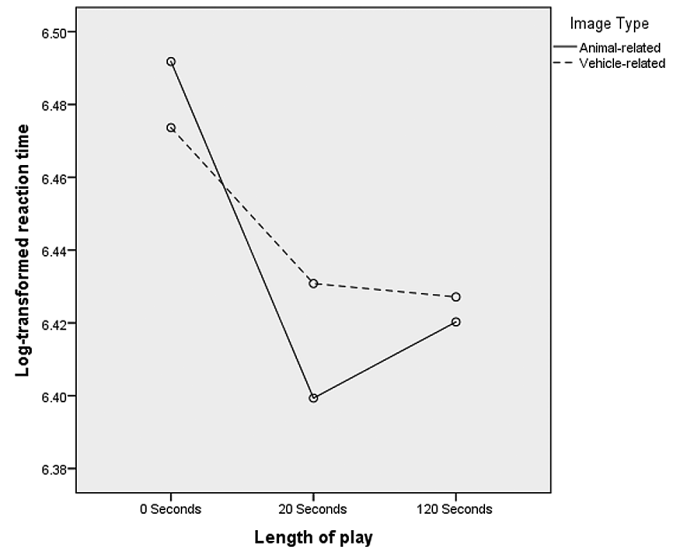


Fig. 9. Line graph showing the interaction between image type and length of play.

have long been concerned that the widespread use of unrepresentative groups of participants in social science research might influence the ecological validity of this scholarship (e.g (Sears, 1986)). Online experiments are argued to allow access to a greater diversity of participants (Nosek, Banaji, & Greenwald, 2002), and hence arguably more generalizable results. Whilst some online groups may be just as unrepresentative as their laboratory-based equivalents (Skitka & Sargis, 2006), this is not thought to be the case when it comes to online game experiments. More specifically, internet-based methods are thought to potentially allow experimenters access to large representative populations of gamers who would could not easily be recruited using a traditional laboratory-based setup (Wood, Griffiths, & Eatough,

2004). This is reflected in the composition of the population outlined above – as noted, 267 out of the 460 people recruited played games at least once a day, and only 36 participants played once a week or less. In addition to the participant-related benefits discussed above, there are various other advantages of this approach. For instance, as experimenters are not physically present, experimenter effects and demand characteristics are thought to be reduced, if not eliminated in online experiments (Joinson, 2007).

However, online experimentation is not without limitations. These largely centre on a lack of experimental control. Whilst experimenters in the laboratory can monitor a participant's behaviour in order to make sure that they are "involved and serious" (Kraut et al., 2004), the same is not true of online experiments. In this case it is comparatively more difficult for experimenters to determine whether a participant's results are serious, and whether they are the product of either intentional or unintentional deception (Reips, 2000). Whilst the issues outlined above cannot be completely eliminated, there are several considerations which researchers can make to mitigate their effects. For instance, potentially "non-genuine" responses can be identified within a dataset as they tend to be either inconsistent or extreme (Wood et al., 2004). They can then be excluded from analysis. In a similar fashion, participants themselves can be screened. Alternatively, online experiments may require larger sample sizes in order to compensate for the behaviour of participants who are "not diligent" (Kraut et al., 2004). These strategies appear to be effective, with several reviews of online experiments reporting that they produce similar results to their laboratory equivalents (e.g. (Dandurand, Shultz, & Onishi, 2008; Gosling, Vazire, Srivastava, & John, 2004; Lutz, 2015)).

Taking an online approach is common in studies of player experience (e.g. (Bowey, Birk, & Mandryk, 2015; Klimmt, Hartmann, & Frey, 2007)). It has also begun to feature in the VVG literature. For instance, in (Williams & Skoric, 2005), researchers were interested in finding out whether playing a violent online game led to long-term increases in aggression-related cognitions and behaviours. Therefore, they recruited 213 participants via online message boards. Some participants played a violent online game for a month, whilst others acted as a control group and did not play a game. Both groups completed measures of aggression-related cognitions and behaviours before the experiment began, and again after a month. Results indicated that playing a VVG had no effect on aggression-related variables.

4.2.8. Procedure

Players first completed an informed consent and demographics screen, and indicated that they were ready to begin the experiment. After this, what participants did next differed based on the experimental condition that they were placed in. Players in the 'control' condition completed the image categorisation task and then were debriefed via a short video presentation. Players in the '20 Seconds' condition first played the game outlined above for 20 s, completed the image categorisation task, and then were debriefed via the same video. Players in the '120 Seconds' condition played the game for 120 s, completed the image categorisation task, and then were debriefed in the same fashion.

4.3. Results

Means and standard deviations for each treatment are presented below. These statistics are based on the log-transformed reaction times of participants.

The effects of length of play (control, 20 Seconds, 120 Seconds) on reaction times to animal and vehicle-related images was tested via a 3×2 mixed-design ANOVA, with length of play as a between-participants factor and image type as a within-participants factor.

Results indicated that there was no statistically significant main effect for image type, $F(1,457) = 0.692$, $p = 0.406$, $\eta^2 = 0.002$. There was a statistically significant effect for length of play, $F(2,457) = 5.709$, $p = -0.004$, $\eta^2 = 0.024$. There was a statistically significant interaction effect between length of play and image type, $F(2,457) = 3.183$, $p = 0.042$, $\eta^2 = 0.014$.

Planned comparisons investigated whether the significant interaction effect occurred between control and 20 s, or control and 120 s.

In the first of these comparisons, the effects of length of play (control, 20 Seconds) on reaction times to animal and vehicle-related images was tested via a 2×2 mixed-design ANOVA, with length of play as a between-participants factor and image type as a within-participants factor. There was no statistically significant main effect for image type, $F(1,309) = 0.445$, $p = 0.505$, $\eta^2 = 0.001$. There was a statistically significant effect for length of play, $F(1,309) = 8.334$, $p = 0.004$, $\eta^2 = 0.026$. There was a statistically significant interaction effect between length of play and image type, $F(1,309) = 6.174$, $p = 0.013$, $\eta^2 = 0.020$.

In the second comparison, the effects of length of play (control, 120 Seconds) on reaction times to animal and vehicle-related images was tested via a 2×2 mixed-design ANOVA, with length of play as a between-participants factor and image type as a within-participants factor. There was no statistically significant main effect for image type, $F(1,316) = 0.325$, $p = 0.569$, $\eta^2 = 0.001$. There was a statistically significant effect for length of play, $F(1,316) = 6.238$, $p = 0.013$, $\eta^2 = 0.019$. There was no statistically significant interaction effect between length of play and image type, $F(1,316) = 1.597$, $p = 0.207$, $\eta^2 = 0.005$.

Follow-up simple effects analyses were undertaken via a series of three repeated measures ANOVAs, with image type as a within-participants factor in each (animal, vehicle). The first of these analyses revealed that there was no significant difference between reaction times to different image types for participants in the control condition, $F(1,168) = 1.662$, $p = 0.199$, $\eta^2 = 0.010$. The second of these analyses revealed that there was a significant difference between reaction times to different image types amongst participants who had played the game for 20 s, $F(1,141) = 5.109$, $p = 0.025$, $\eta^2 = 0.035$, with reactions to vehicle-related images being significantly slower than reactions to animal-related images ($M = 6.430$ vs. $M = 6.399$). The third of these analyses revealed that there was no significant difference between reaction times to different image types amongst participants who had played the game for 120 s, $F(1,148) = 0.249$, $p = 0.619$, $\eta^2 = 0.002$.

4.4. Discussion

These results again suggest that priming does not happen in video games. Neither people who had played the infinite runner game for 20 s, nor those who had played the game for 120 s, were significantly faster at categorising vehicle-related images than those who had not played the game. This suggests that the lack of a priming effect seen amongst the participants in the lab-based experiment reported earlier in this paper also generalises to a more ecologically valid sample of video game players in their natural environment.

In addition to replicating the lack of a priming effect seen in Experiment 1, this experiment again suggests that negative priming happens in video games. Indeed, it seems to happen even when people only play a game for 20 s. A significant overall interaction effect occurred between image type and length of play. Planned comparisons clarified that this effect occurred between players in the control condition (i.e. people who had not played the game at all) and players in the 20 s condition. Whilst people who had not played a vehicle-themed game were quicker at reacting to images

of vehicles (6.473) than images of animals (6.491), the opposite was true for those who had played the vehicle-themed game for 20 s. These participants were instead *slower* at reacting to images of vehicles (6.430) than images of animals (6.399). In other words, playing a vehicle-themed game for 20 s caused the relative slowing of reaction times to vehicle-related images, indicating negative priming of this concept. This image of the effects of play was also reflected in the simple effects analysis. There was no significant difference between reaction times to vehicle-related and animal-related images amongst participants in the control condition. However, after playing the game for 20 s, a significant difference emerged, with participants reacting significantly more slowly to vehicle-related images than to animal-related images. This result largely reflects the data collected in Experiment 1, in which a similar negative priming effect was observed. However, in contrast to Experiment 1, in which negative priming was observed after 200 s of play, no negative priming (or priming) was observed amongst those individuals who played the infinite runner game featured in this experiment for 120 s.

Before moving on, it is crucial to clarify the importance of both the significant effect described above (an interaction effect between length of play and image type) and the main effect of length of play which was observed within the study. The study's results contain a main effect: Participants who not played the game (i.e. those in the control condition) were slower at categorising images *in general* (mean reaction time = 6.482) than participants who had played the game for either 20 s (mean reaction time = 6.414) or 120 s (mean reaction time = 6.423).

It is key to make clear that this main effect does *not* reflect the priming of a specific concept – it just shows that players are faster at categorising everything after playing a game, regardless of the stimulus that they are being asked to categorise. This makes sense: playing video games is well known to impact factors such as spatial cognition and dexterity, and have a positive effect on the speedy and successful completion of a variety of different tasks. However, it is the significant interaction effect which shows priming (or negative priming) of a concept: This effect shows that participants are getting better at categorising images in a significantly unequal way. They (overall) may be faster at categorising images in general. However, the interaction shows that they are getting faster at categorising images of vehicles at a significantly slower rate than they are getting faster at categorising images of animals.

The interaction effect is therefore used to test for a negative priming effect as it compares reaction times to images of animals with reaction times to images of vehicles. The main effect cannot show the priming of a specific concept as it represents reaction times pooled across both images of animals and images of vehicles. It is furthermore important to note that the statistical analysis used here (i.e. testing our hypothesis via looking for an interaction effect rather than main effect) is consistent with similar analyses in the literature – (See Section 2.3.1).

5. Conclusions

5.1. Theoretical implications

The research presented here has two main theoretical implications for learning and behaviour change in video games. Firstly, these results suggest that priming-centred models of behaviour change in games such as the GAM and GLM may be inaccurate in their predictions of both how and why video games cause changes to player behaviour. Proponents of these models work under the assumption that the concepts which are depicted in a game are primed, and that this priming contributes to eventual changes in player behaviour. According to this point of view, playing a

prosocial game such as *Lemmings* should prime prosocial concepts like 'helping' and 'rescuing', leading to prosocial player behaviour. Similarly, playing *Call of Duty* might prime the concepts 'shooting' and 'killing' simply because this game contains depictions of these things. The priming of these aggressive concepts by aggressive content is predicted to then lead to aggressive behaviour both in the short-term and in the long-term.

However, the results presented here contrast with this perspective. We conducted two experiments which investigated whether priming occurs in video games when known confounds from the literature were eliminated from an experimental design. However, we did not find any evidence that playing a video game led to the priming of the concepts which featured in that game. Not even using 460 participants in an experiment (Experiment 2) allowed the detection of a priming effect – indeed, to the contrary, a significant effect running in the opposite direction was observed twice during the studies reported here. Surely whilst repeatedly not observing a significant priming effect in a variety of experiments is convincing evidence that this effect may not exist, even more convincing is the existence of a significant effect going in *the opposite direction*.

The generalizability and trustworthiness of this result is further supported by the population used in Experiment 2. Whilst much research on the effects of VVGs makes use of non-representative samples of University students, in Experiment 2, only 36 of the 460 participants who were recruited played video games once a month or less. Indeed, 388 of the 460 played at least once a week.

Since content does not seem to prime in video games *in general*, it also seems unlikely for it to specifically happen in violent games. This observation strongly conflicts with the point of view outlined above. However, it is in keeping with recent research which has questioned whether the priming of aggression-related concepts in the VVG literature really is due to the violent content of these games. Researchers such as [Kneer et al. \(2016\)](#) instead propose that these effects can be explained by confounding from third factors such as incompetence. The experiments in this chapter used proper controls to eliminate the presence of proper confounds, and repeatedly found no priming effects. The results of these experiments therefore lend further credence to this alternative explanation for priming in the VVG literature. This supports the argument that new theories of how and why video games might lead to changes in behaviour are needed: If concepts are not primed by game content, then this priming cannot spread to related knowledge structures. If these knowledge structures are not primed, then their activation cannot lead to short-term changes in behaviour and their reinforcement cannot lead to long-term changes in behaviour. In other words, these results suggest that many of the mechanisms for learning and behaviour change which the GLM and GAM propose may not function when playing many games. In the words of one academic, "the time has come to retire the General Aggression Model" ([Ferguson & Dyck, 2012](#)) – and perhaps the General Learning Model too.

Secondly, this research provides support for other research which has argued that the methodology which is used to investigate priming in video games is often seriously flawed. As noted in Section 2.2, experiments in the video game effects literature commonly make use of an approach to experimentation in which wholly different games serve as different experimental conditions. In comparison to the laborious process of custom-building bespoke games, this approach is quick and easy to implement. However, an increasingly common concern amongst academics is that it may lead to serious errors in the interpretation of experiments. More specifically, whilst a significant priming effect may be observed between (for instance) a violent game and a non-violent game, it is impossible to confidently say whether this effect's existence is due

to differences in content between these games, or whether it is due to some other difference between these games, for instance frustration, difficulty, or arousal. These results feed directly into this area of debate. Not only was priming not observed in the carefully-controlled experiments reported here, but the opposite result was observed on multiple occasions (negative priming). When coupled with the null effects which have recently been produced in similarly well-controlled experiments in the literature (See Section 2.2), this disparity strongly supports the argument that the methodology outlined above may not be fit for purpose.

5.2. Practical implications

As the authors of the GAM point out, the long-term changes in aggressive behaviour which their model predicts are largely rooted in priming. Whilst “temporary mood states and arousal dissipate over time” (Anderson, 2003), predicted long-term changes in behaviour are largely due to the repeated priming of aggression-related concepts by the aggression-related content of VVGs. This, in turn, leads to players behaving violently in the long-term. The studies conducted here strongly suggest that the priming effects which the GAM predicts as a consequence of VVG content may not materialise. The societal effects which these models predict therefore consequently seem greatly reduced. Under the GAM, without priming effects, the consequences of playing violent or are largely limited to “temporary mood states and arousal”. In other words, it still may be the case that playing a famously frustrating VVG like *Dark Souls* may cause a player to become angry and aroused, and then act aggressively towards nearby individuals. However, it does not seem like the stabbing and killing action in this game will prime these concepts and thereby cause the player to learn that these are appropriate behaviours to use in real-world contexts in the way that the GAM predicts, either in the short term or the long term. In this way, *Dark Souls* seems only as likely to lead to violent behaviour as a similarly arousing and angering game such as *Flappy Bird*.

When it comes to this observation in the context of the GLM, however, the absence of a priming effect may prove to be a double-edged sword. The General Learning Model generalises the GAM to cover the learning of *any* behaviour from games, and not merely aggression-related behaviours. Under the GLM, playing a game which depicts some behaviour leads to the learning of that behaviour. This model therefore provides a comprehensive explanation of how video games can be used to effect positive behaviour change. For instance, under the GLM, playing the healthy-eating themed serious game *Squire's Quest* would teach positive behaviours related to ingesting lots of “fruit, 100% fruit juice, and vegetables” (Baranowski et al., 2003). This effect theoretically is caused by the same priming mechanism proposed in the GAM. Since it seems that this process may not happen, it also seems that learning useful behaviours by playing games may be a more difficult process than has previously been assumed.

However, caution is warranted when applying the results of this research to behaviour in the real world. The experiments conducted here investigate priming, and do not directly look at whether playing games leads to changes in behaviour. Therefore, whilst these results can show that playing games do not lead to priming, and hence do not lead to behaviour change in the way that the GAM and the GLM predict, they cannot suggest whether or how playing games leads to behaviour change *absolutely*. Drawing such a conclusion from the evidence presented here is far outside the scope of this research.

There is a further practical implication to these results. These results suggest that the content of video games has little effect on priming. This supports the position of academics who propose that

the major factor determining the aggression-related effects of VVGs are gameplay-related things such as frustration and difficulty (See Section 2.3), rather than the content of these games. This would suggest that priming-related effects of VVG play may attenuate over large amounts of time, as a game becomes progressively less frustrating and difficult to the player. To the best of our knowledge, no rigorous longitudinal experiment has specifically been conducted to study the interaction between length of exposure to a game, and the priming of in-game concepts. However, this research suggests that just such an experiment would be of great value to academics who are interested in the ability of video game play to effect any form of behaviour change.

A final point regarding the practical significance of these results concerns negative priming. As described in Section 5.1, the observation of a negative priming effect, albeit fleetingly, in these studies may have some theoretical implications. However, it is important to also consider the possibility that this effect may have practical importance in and of itself. As noted in Section 2.3, negative priming is theorised to be the consequence of a mechanism which filters out distracting information in order to focus attention on a task at hand. As such, the negative priming effect observed here could suggest that gamers are paying less attention to many of the concepts that feature in the games that they play, and are instead narrowing their attention to the tasks of special manipulation that they need to do in order to ‘win the game’. This would align negative priming with other well-known effects of playing video games – for instance, boosts to spatial cognition and dexterity.

5.3. Limitations and future work

Overall, these results bear important implications for the effects of violent video games. They suggest that priming does not necessarily happen in these games, and that the learning effects of video game play may be overstated. The importance of these assertions are supported by both the variety of games in which a lack of priming was seen, by the representativeness of the games, the representativeness of the participants who took part in the experiments, and also by the fact that similar effects were observed both inside the laboratory and in an online experiment.

However, this research is not without its limitations. The most important of these limitations concerns negative priming. As described in Section 5.1–5.2, the observation of a negative priming effect in these studies may have key theoretical and practical implications. However, it is crucial to not be overzealous about the potential of this novel effect before ensuring that it can be reliably replicated across a variety of different games. Whilst negative priming was repeatedly observed in the experiments which featured here, there was one occasion where it was *not* observed. In Experiment 2, whilst negative priming was observed for participants who had played the game for 20 s, no such effect was observed for those who had played it for 120 s. This result is interesting because in the previous experiment, people who had played a maze game for a similar length of time (200 s) *did* show negative priming. This fragility suggests that negative priming may be not just a small effect, but a delicate one which only occurs under certain specific conditions. However, the factors which may have caused this effect to not be observed in Experiment 2 are unclear. As part of further research, it will be necessary both to discover what effect size might be associated with negative priming in games, and also investigate what contexts this effect may (and may not) be observed under. It may be the case that this effect is so small, or so delicate, that its importance is negligible.

A second major limitation of this research is to do with the fact that violent video games are not a static form of media. New gameplay mechanics are constantly cropping up in this ever-

evolving form of entertainment. It is a very real concern that innovations in VVG design and play may cause important changes to the relationship between VVG play and priming. The legitimacy of this concern can be illustrated with an example from the recent VVG *Grand Theft Auto V*. Much of the action of this game is based around the kinds of traditional gameplay mechanics which featured within the experiments reported above. However, in one controversial scene, the player engages in a 'mini-game' in which they must torture a defenceless NPC. As one journalist notes, "this interactive portion has you pulling teeth and waterboarding your victim, and there's no way to skip the scene or opt out of the action" (Sliva, 2013). Whilst the research presented here suggests that the priming of aggression-related concepts does not occur during the play of most VVGs, it would be cavalier to extend this argument to an example such as this.

In other words, violent video games are changing and diversifying. Indeed, many have hailed 2017 as 'the year of VR', with cutting-edge virtual reality VVGs like *Superhot VR* and *GORN* gaining in increasing popularity in recent months. The literature must change and adapt alongside VVGs themselves if it is to remain relevant. Therefore, in order to ensure that the conclusions drawn from this paper remain valid, continual additional experimental work is needed. This work should particularly be used to guard against the possibility that novel features of modern VVGs increase priming. It may well be the case that these features have little effect on this factor. However, it is crucial to bear in mind the possibility that this may not always be true.

This paper contains strong evidence which contradicts the claims of academics who argue that VVGs lead to the priming of aggression-related concepts. In neither Experiment 1 nor Experiment 2 did playing a game lead to priming. This absence of an effect runs directly counter to the predictions of prominent figures in the VVG effects community. These results also contradict several pieces of experimental evidence from within the VVG effects literature. When the tightly-controlled way that these experiments were run is taken into account, this contradiction implies that the VVG literature may contain several false positives. In order to truly understand what the effects of VVGs are on their players, previous results which have indicated that VVG play leads to priming need to be replicated, and alternative explanations for the effects which these experiments show need to be explored.

This scrutiny of the VVG literature should help us to better understand what the effects, if any, of playing VVGs are. Furthermore, it should suggest credible alternative theories for how these effects might be determined. It may be the case that playing VVGs really does lead to negative effects on players. It may well even be the case that these effects are currently leading to societal damage. However, in order to understand what these effects are, and whether they really exist, it is necessary to first deal with any misleading evidence within the experimental literature.

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