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Creativity-related elements of cognition and emotions influenced by videogames

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ABSTRACT
To date, the impact of various types of videogame stimuli on creativity-related elements of cognition and emotions is unknown. The current research investigated the effects of action and non-action visual videogame stimuli on cognitive load, attentional breadth, and emotional processes. To measure cognitive load, participants responded to a red fixation cross during videogame presentation (RT task). Following the stimuli, the effects on attentional breadth were measured using the Navon letter task and emotional responses were obtained using a self-report scale. Results from the simple RT task showed that viewing the action videogame stimuli were associated with greater cognitive load compared to the no game condition. The Navon task revealed that attentional breadth was similar in the action game and the no-game condition, but that attentional breadth was narrowed in the non-action game condition. The emotional responses after viewing action videogame stimuli were less pleasant than viewing non-action videogame visual stimuli but more arousing than a no game control condition. These findings show that visual stimuli used in action and non-action videogames differentially affect creativity-related elements of cognition and emotions.

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Creativity; cognitive load; attentional breadth; emotions; videogame play

1. Introduction

Until now, there has been a dearth of interdisciplinary research that has addressed the interplay between the effects of videogames on creativity-related cognitive processes (e.g. cognitive load and attentional breadth), and the role of emotions that are involved in this process (cf. Bennett, Maton, and Kervin 2008; Blanco-Herrera, Gentile, and Rokkum 2019; O'Neil et al. 2021). In media research, Bowman (2018) emphasised the interactive and multifaceted demand of playing videogames, which includes cognitive, emotional, physical and social dimensions of gaming experiences. Previous videogame research has highlighted the point that high cognitive demand is triggered during gameplay (Dale et al. 2020; Bediou et al. 2023; Green and Bavelier 2012; Spence and Feng 2010), which could affect subsequent cognitive processes at different levels, such as critical thinking, attentional breadth, and creativity (Angelelli et al. 2023; Blanco-Herrera, Gentile, and Rokkum 2019; Chandler and Sweller 1991; Mercier and Lubart 2023; O'Neil et al. 2021; Sweller 1988). In addition, the role of emotional elements of videogame play are significant in affecting gameplayers' cognitive processes (e.g. Grodal 2000; Ivarsson et al. 2013; O'Neil et al. 2021; Pallavicini, et al.,2021). However, the relationship amongst these relevant cognitive and affective mechanisms within gameplay overall is unclear and are rarely examined together; but rather often investigated separately in videogame research (Blanco-Herrera, Gentile, and Rokkum 2019; Mercier and Lubart 2023; O'Neil et al. 2021).

This is an important area for further interdisciplinary research because creativity, including in human–computer interaction contexts, is becoming ever more important in our world in which technology and conditions are rapidly changing (Morris 2020). Creativity involves a process of both generative and analytical thinking states (Anderson et al. 2023; Hou et al. 2023; Howard-Jones 2002; Torrance 1966), in which novel, whole, and effective solutions are generated that have value in a given context (Mishra, Henriksen, and Group 2013; Robinson and Aronica 2009). New and potentially creative thoughts would be produced in the generative thinking state, to be further evaluated in the critical or logical thinking state, so that the final creative production can be both novel and appropriate (Sternberg and Lubart 1999).

It is important to highlight the point that videogame play has shown to produce long-term effects of creativity-related elements of cognition and emotions. For

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example, research has shown robust evidence of overall positive correlation between videogame play (e.g. Minecraft) and creativity (measured by alternative task, remote association task, and Torrance tests of creativity thinking; cf. Torrance 1966) in relation to other none gameplay activity, including watching a TV show (Blanco-Herrera, Gentile, and Rokkum 2019; Jackson et al. 2012). Recently, using a cross-sectional study design, Mercier and Lubart (2023) found that videogame play inarguably have effects on both cognitive and affective processes, such as optimism generated through playing videogames may mediate increased levels of creativity in the workplace. Nonetheless, it is important to highlight that cross-sectional studies cannot confirm direct causal relationships, but they do provide initial evidence and reasoning for further studies to examine the effects of videogames on creativity, especially studies that unpack the complexity of the effects (i.e. the cognitive and affective processes of videogame stimuli on creative thinking mechanisms). However, it is important to note that because creative thinking processes are very complex, to unpick our understanding of the processes further experimental studies (examining short-term effects; which is the design of the present study) are needed to investigate the mechanistic interplay of specific creativity-related cognitive processes and emotional elements, which are deemed as significantly influential in videogame-creativity literature.

Indeed, action videogames are inherently distinctive from other genres (e.g. *casual* or *strategy* games) in the elements of visual graphics (e.g. enemies appearing anywhere within a large visual-spatial view and rapidly moving visual stimuli, resulting in heavy cognitive load on perceptual, attentional and cognitive skills; Bediou et al. 2023; Green and Bavelier 2012). Videogame graphics have a transformative impact on the nature of human interactions with digital media (Väyrynen, Helander, and Jalonen 2023), by mediating perceptual and cognitive processes (Hegarty 2011), as well as emotional responses (Lane, Chua, and Dolan 1999). Variances in shape, colour, and distributions of space convey different visual representations (e.g. symbols for objects, events, or abstract information), trigger different perceptual and cognitive processes as they store information that activate working memory resources and other subsequent creativity-related processes (Hegarty 2011), including cognitive load, working memory, attentional breadth (Kasof 1997); and emotions (e.g. arousal, desire, positive and negative emotions; Grodal 2000; Lane, Chua, and Dolan 1999). In addition, the emotional influences activated by exposure to visual stimuli may be largely unconscious (Atkinson and Adolphs 2005); and unnoticeable by individuals who are regularly exposed to videogame play without conscious awareness (Yeh 2015). In the following section we highlight the point that to date little interdisciplinary research has addressed the interplay between the effects of videogame stimuli on creativity-related elements of cognition (e.g. cognitive load and attentional breadth), and the role of emotions that may be involved in this process. And, to bridge this lack of knowledge, the current study aims to expand our understanding of the underlying cognitive mechanisms evoked by visual stimuli, which are in different types of videogames, whilst simultaneously investigating emotional responses.

2. Theoretical development and literature

2.1. Visual stimuli of videogames, game schema theory, and cognitive load theory

Human exposure to different kinds of visual stimuli may deliver different conceptual associations, or evoke different types of emotional processes. For example, the presence of external visual representations in designers' work environments have been found to facilitate higher-order cognitive and perceptual processes, such as creative design performance (Goldschmidt 2015; Goldschmidt and Smolkov 2006). Importantly, even subtle differences in otherwise similar visual displays may communicate information differently, thus affecting cognitive performance (Hegarty 2011; Hegarty, Canham, and Fabrikant 2010). For instance, Yeh (2015) showed that playing an action videogame, with complex forms of visual stimuli (i.e. representing the hero, forms of weapons and enemies, and battlefields), enhanced players' scores of originality, elaboration, and flexibility (measured via an Ideas Generation Task; as per Howard-Jones and Murray 2003, 157), in comparison to playing a non-action videogame.

Indeed, *gameplay schema* (Lindley and Sennersten 2008) and cognitive load theories (Chandler and Sweller 1991; Sweller 1988; although not directly addressing the case of videogame stimuli) are useful constructs to explain the fundamental cognitive mechanisms and interrelated processes associated with exposure to videogame stimuli. In this regard, Lindley, Nacke, and Sennersten (2008) argued that a gameplay schema (which builds on *schema theory*, Mandler 1984) represents a cognitive structure where different aspects of cognitive resources required during videogame play are connected. Thus, gameplay schema facilitate cognitive comprehension and manifest cognitive-motor operations required during the changing demands of game-player interactions, to achieve a specific goal or sub-goal embedded in the game environment; and a key consideration here, relevant to the present study, is that each videogame has its own gameplay schema, including rules of the games that lead to differential sequences of and complexity of visual stimuli presentation (Lindley, Nacke, and Sennersten 2008; Lindley and Sennersten 2006). As such, videogame stimuli could be regarded as *primes* that interconnect other mental processes and trigger other cognitive operations that can be carried over and have a lingering effect on subsequent cognitive processes, including creativity (Shiffrin and Schneider 1977). This can be supported by the associative theory of creativity (Kenett 2019; Mednick 1962) that remotely associated ideas stored in semantic memory are integrated to generative creative ideas.

Chandler and Sweller (1991) theorised three types of cognitive loads; cognitive load referring to 'any demands on working memory storage and processing of information' (Schnotz and Kürschner 2007, 471): *intrinsic* cognitive load, which deals with task relevant information; *extraneous* cognitive load, which deals with the task – irrelevant information; and, *germane* cognitive load, which deals with new schema construction and learning relating to the task (Brunken et al. 2003; Hollender et al. 2010; Sweller 1988; Sweller et al. 1990). The demands in these types of cognitive load depends on the complexity of the given information and task materials which affect attentional processes.

In application to videogame play, Cutting and Deterding (2024) introduced the *Task-Attention Theory of Game Learning*, identifying that videogame play involves a process of directing players' attention both *onto* the game and *within* the game onto task-relevant information, noting that to date understanding of the interactions between these mechanisms was not complete. Specifically, the theory includes that top-down executive functioning, such as controlled attentional sampling and selection which are affected by attentional demands – pressures and perceptual and cognitive loads: thus, heightened task-related cognitive load would lead to reduced available resources for top-down attentional control, including broadening and narrowing attentional breadth. This is in line with the work of Beaty et al. (2014) on creative thinking, who found that generative or divergent thinking may involve both associative (bottom-up) and executive (top-down) processes. Therefore, in the context of videogames, the complexity of videogame visual stimuli may influence both associative and executive processes which consequently affect creative idea generation.

Specifically, and relevant to the present study, previous studies on action videogames have shown that high cognitive demand is associated with the requirement of the players in tracking multiple complex visual stimuli, whilst simultaneously ignoring the unnecessary stimuli and focusing on the targets required in the games (Bediou et al. 2023; Dale et al. 2020; Green and Bavelier 2006, 2012). In this respect, and in consideration of cognitive load theory (Chandler and Sweller 1991; Sweller 1988), we would anticipate that conceptual associations evoked by the videogame stimuli to affect subsequent higher order cognitive processes at different levels. The theory claims that information carried within the visual stimuli is processed via the activation of a 'visual-spatial sketchpad', up to a limit of duration and capacity during working memory processes – to deal with the demands of an ongoing given task (Baddeley 1992, 2012). In such a process, mental schemata may be newly constructed by potentially connecting and combining with previously formed schema stored in long-term memory for further creative idea generation. Therefore, we postulate that although the higher cognitive demands caused by complex visual stimuli might, one the one hand increase the cognitive effort *during* action videogame play, on the other hand have a lingering effect that may trigger long-term memory processing that influences *subsequent* greater semantic richness. Nonetheless, the above processes are intrinsically connected to attentional processes, attentional breath and emotional responses involved in viewing videogame stimuli.

2.2. Visual stimuli of videogames and attentional breadth

Visual stimuli within videogame play involves a number of cognitive mechanisms, including top-down or bottom-up attentional processes (Boot et al. 2008; Green and Bavelier 2012; Oei and Patterson 2013; Spence and Feng 2010), which are related to attentional breadth (Spence and Feng 2010). Notably, attentional breadth is the *gate* that associates attention with other higher order cognitive processes and creativity (memory, metacognition, executive functions etc.; Spence and Feng 2010). Videogame play involves different forms of goals that require players to pay attention to differentiate goal-relevant and goal-irrelevant visual stimuli, which involve higher cognitive processes, including the demand for attentional breadth to various amounts depending on videogame type (Oei and Patterson 2013).

Action videogame play has been shown to improve players' visual attentional breadth throughout the visual field, in comparison to non-action videogames (Bediou et al. 2023; Green and Bavelier 2006; Spence and Feng 2010). Spence and Feng (2010, 97) emphasised that action videogames play facilitates the capacity to distribute players' attention over a wide range of the visual field, so that players can recognise stimuli in the peripheral by 'localizing potential targets without fixing [their] gaze on the many objects in the periphery'. This ability allows individuals to process information collected from visual stimuli present in the entire visual field, prior to other higher cognitive processes, in order to proceed with subsequent cognitive and behavioural changes.

Due to the close association between attentional breadth and other cognitive processes, previous literature has distinguished different aspects. For instance, Chung, Busseri, and Arnell (2022, 2) suggest that *cognitive breath* can be categorised broadly into *attentional/perceptual breadth* (being 'the tendency to concentrate attention locally in a small region of space versus allocating it more globally over a larger region') and *conceptual breadth* ('breadth and flexibility of thought'). Moreover, *visual attentional breadth* (or *field of view* which has been defined as 'the visual area in which information can be acquired within one eye fixation', Ball et al. 1988, 2210) is another example. Such dimensions are often studied separately within the videogame literature (Bediou et al. 2023; Green and Bavelier 2006; Spence and Feng 2010) and creativity research (e.g. Fredrickson and Branigan 2005; Friedman et al. 2003; Kasof 1997; Kounios et al. 2008), even though they are closely connected. Very limited interdisciplinary research has investigated to what extent different videogame types impact on players' creativity. However, in 2015 Yeh hypothesised that the complex visual display in action videogames might broaden attentional/perceptual breadth, benefiting the process of remote idea associations, which generates new ideas and enhances creativity. Nonetheless, to the knowledge of the present authors there is no empirical evidence to date to support this claim.

2.3. Emotional content of videogame stimuli and its potential influence on attentional breadth

We should also consider that there has been a growing interest in the effects of videogames on players' emotions (e.g. Ivarsson et al. 2013; Pallavicini, Pepe, and Mantovani 2021). A review by Granic, Lobel, and Engels (2014) highlighted the point that the emotional benefits of videogame play were found to generate positive feelings, improve mood and positive emotions. Specifically, videogames have shown to enhance relaxation and reduce stress (e.g. Russoniello, O'Brien, and Parks 2009); promote mild positive emotions, such as relaxation (Parnandi et al. 2014); and even produce the most intense positive emotional experiences such as pleasure and desire – as gamers may view outcomes as an intrinsically rewarding activity (e.g. McGonigal 2011).

Theories of emotion (popular in emotion–cognition research), such as valence-arousal (Russell 1980) and valence-motivation dimension of emotion (Gable and Harmon-Jones 2008, 2010b) provide some foundations for understanding the effects between videogame play and emotions. Russell (1980) proposed the circumplex model of emotion that all emotional states are compositions of the two fundamental neurophysiological systems: valence (a pleasure-displeasure continuum) and arousal (high and low arousal or alertness). For example, relaxation is a state of median-high pleasure coupled with low activation of arousal; whereas stress is a median-high displeasure coupled with median-high activation state. Broaden-and-build theory (Fredrickson and Branigan 2005) and positive affect-creativity research suggest that positive emotions signal a safe and relaxing environment, leading to more global and heuristics cognitive process which enhance cognitive flexibility and facilitate creative idea generation and problem-solving performances (Ashby and Isen 1999; Isen, Daubman, and Nowicki 1987). Furthermore, high-arousal positive emotional states (e.g. happiness) broaden attentional breadth and therefore benefit creative cognition (Frieman and Förster 2010).

Moreover, Gable and Harmon-Jones (2008, 2010b) emphasised the motivational dimension of emotion: proposing valence (positive vs. negative) and intensity of approach vs. avoidance motivation (i.e. the drive to approach or avoid an object or goal) as two orthogonal dimensions of emotions. They explained that most positive emotions are usually associated with approach motivation (cues of reward) and most negative emotions with withdrawal motivation (cues of threat); however, positive emotions can vary in approach motivational intensity, differing the subsequent cognitive processes, such as attentional breadth. For example, Gable and Harmon-Jones (2008, 2010b) found that positive emotion high in approach motivation (e.g. desire elicited by goal attainment visual appetitive stimuli) narrowed attentional breadth and cognition; whereas, positive emotion low in approach motivation (i.e. relaxation elicited by post-goal or goal-irrelevant stimuli, such as humorous visual stimuli) broaden attentional breadth and cognition.

In the context of videogames, building upon Russell's (1980) and Gable and Harmon-Jones' (2008, 2010b) models of emotions, Yeh (2015) proposed a tri-dimensional model of emotions by considering valence, arousal and motivation dimensions. And, given the importance of considering a multitude of emotions particularly in the context of videogaming (Grodal 2000; Lane, Chua, and Dolan 1999), the current study adapted Yeh's (2015) approach, assuming that different types of visual stimuli can elicit different types of emotions varying in *valence* (i.e. pleasant/unpleasant), *arousal* (high/low) and *motivation* (high/low approach motivation), as a foundational basis for the conceptual framework of the present study. Concomitantly, however, it is important to highlight the point that emotions may also affect subsequent cognitive processing, such as attentional breadth (e.g. disgust leads to a narrowed attentional breadth, Gable and Harmon-Jones 2010b). Moreover, in this respect, there is also a dearth of research on the emotional content of visual stimuli designed in different types of videogames. Therefore, the current study also aimed to explore the emotional content of visual stimuli from different kinds of videogames.

2.4. The conceptual framework

To bridging the gap, building on Yeh (2015), a conceptual framework was created to test the effects of videogame stimuli on cognitive load, attentional breadth and emotional responses (see Figure 1). The moving stimuli and interactivity in different types of game types could introduce large variances associated with the speeds, movements, sounds, symbolic meanings of the stimuli and contextual graphical design (Bediou et al. 2023). Hence, snapshots of videogame stimuli were used in this study purposefully to control various complexity of perceptual, attentional and cognitive demands which could induce further lingering effects caused by the sudden appearance of unexpected moving objects and the interactivity between the players and the visual stimuli. Two types of videogame stimuli, an action videogame (AG, with complex visual stimuli) and a non-action videogame (NAG with simple visual stimuli) were chosen for the purpose of this study (See 3.2.1).

Firstly, to test whether the cognitive effects of visual stimuli on attentional breadth extends to subsequent cognitive processing a simple reaction time (RT) task measured participants' cognitive load during viewing of videogame stimuli, where slower RTs to a red-fixation cross indexes higher cognitive load (see Figure 1; also, Brunken et al. 2003). It was predicted that viewing the AG visual stimuli will increase cognitive load compared to viewing the NAG, and a no game (NoG) condition. The no-game condition was a blank screen, designed as a visually simple non-emotional stimulus that acted as a control condition to provide baseline cognitive load, attentional breadth and emotional responses, for comparison with the videogame stimuli. The first hypothesis was:

H1a: Viewing action videogame visual stimuli will slow down the response times in the simple reaction time task in relation to non-action videogame condition.

H1b: Viewing action videogame visual stimuli will slow down the response times in the simple reaction time task in relation to no game condition.

Moreover, action videogame stimuli differ from other games in that they are designed with an emphasis on peripheral visual field processing and divided attention (Bediou et al. 2023; Green and Bavelier 2012); and playing this type of game can improve visual attentional breadth throughout the entire visual field (both central and peripheral visual processing). Thus, in addition, in the simple reaction time task, the red-fixation cross is likely to tune participants' visual attention to the centre, causing a narrowing effect on visual attentional breadth. Interactions among these two cognitive processes of attentional breadth in the current study may imply that the demand of the ongoing cognitive processes caused by viewing the action videogame visual stimuli (cf. cognitive load theory, Chandler and Sweller 1991; Sweller 1988) may override the narrowing effect of the red-fixation cross in the simple reaction time task, affecting participants' mechanisms of attentional breadth at different levels (e.g. measured in the visual and perceptual levels, but affected at the cognitive level). Therefore, it was assumed that such lingering cognitive effects on subsequent attentional breadth would be greater after viewing the action videogame stimuli hence producing a compensatory effect on the narrowing visual attentional breadth. Whereas, the other two conditions (NAG and NoG) would not have such compensatory effect, hence, NAG may show a narrowing effect on attentional breadth; whereas NoG may show no effect.

Attentional breadth can be measured by Navon's paradigm (Navon 1977), which present large letters (global level) composed of small letters (local level) in Navon letter task. Within this task, participants are instructed to respond to a composition stimulus at either the large letter or small letter as fast as possible. Typical results are consistently reliable that more interference derived from the global information with local processing than vice versa, indicating the global precedence effect (c.f., Navon 1981). Dale and Arnell (2013) found the global precedence effect measured using Navon letter tasks were highly reliable (the test – retest reliabilities for global and local letters were $r = .66$ and .73, respectively), although this test may only measure a distinct aspect of global-local processing associated with attentional breadth (for more details see Dale and Arnell (2013) and section 3.2.3 of the present paper), and in doing so it was hypothesised:

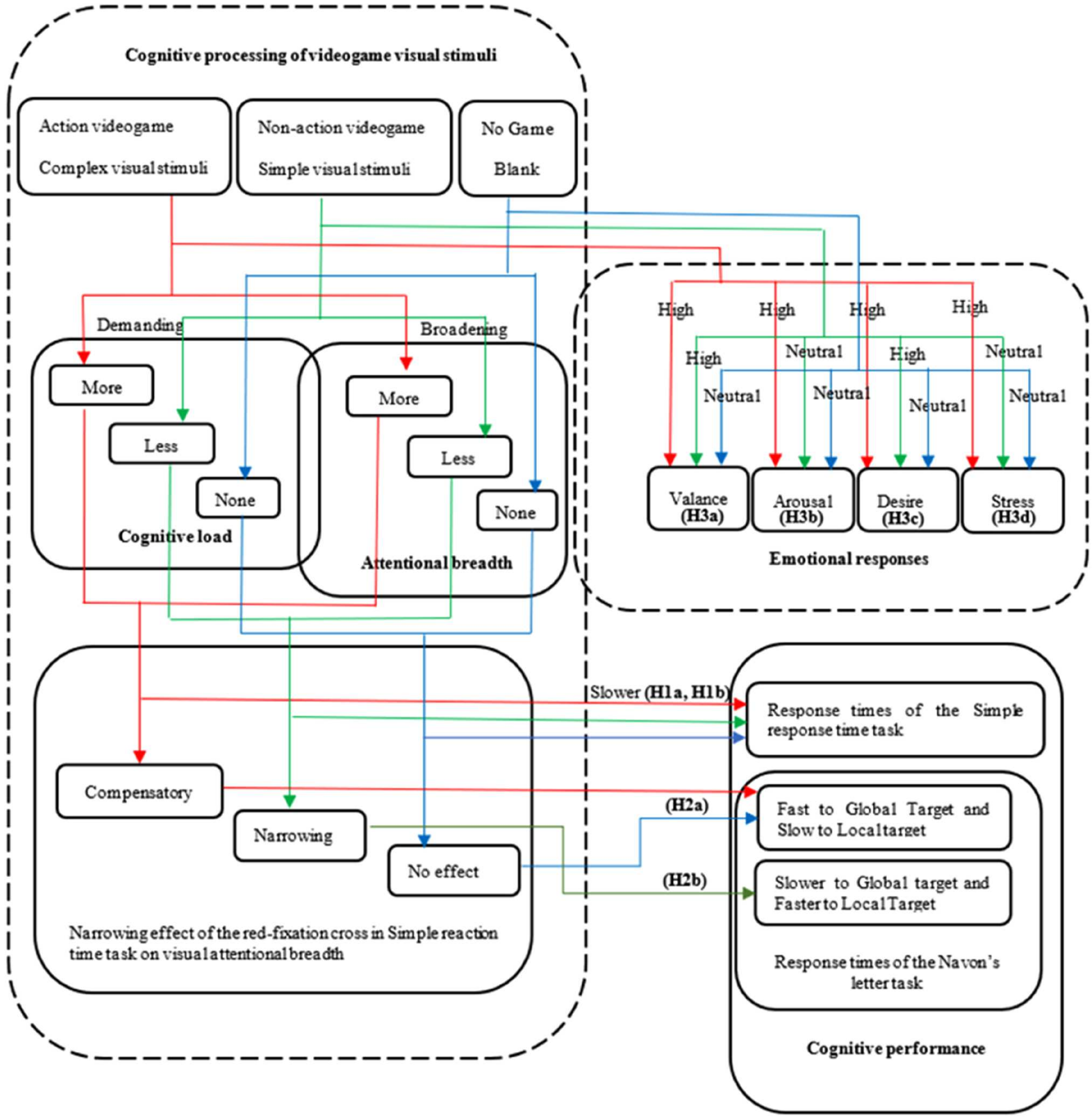

Figure 1. The conceptual framework: Effects of viewing videogame visual stimuli on cognitive load, attentional breadth and emotional responses.

H2a: Viewing action videogame visual stimuli will not reduce attentional breadth, resulting in no differences in reaction times for global targets between the action game condition and the no-game condition, and no differences in reaction times for local targets between the actiongame condition and the no-game condition.

H2b: Viewing non-action videogame visual stimuli will reduce attentional breadth, resulting in slower response times to global targets, and faster response times to local targets in comparison with action videogame condition and no-game condition.

Finally, in terms of investigating the effects of videogame stimuli on affective processes, following from Yeh (2015), it is assumed that viewing action videogame stimuli will also activate positive emotions (i.e. pleasantness and desire), coupled with a high level of arousal and stress, compared to the non-action and no-game condition. Therefore, it was hypothesised that:

H3a: Viewing both the action videogame and the non-action videogame visual stimuli will evoke similar degrees of pleasant emotions (i.e. valence) which are higher than the no game condition.

H3b: Viewing the action videogame visual stimuli will evoke greater arousal than viewing the non-action videogame visual stimuli and the no game condition.

H3c: Viewing both action and non-action videogame visual stimuli will evoke similar levels of desire which are higher than the no game condition.

H3d: Viewing action videogame visual stimuli will evoke more stress than viewing non-action videogame visual stimuli and the no game condition.

3. Methodology

3.1. Participants

Twenty-four undergraduate psychology students took part in the current study (Mean age = 21.63; *SD* = 3.94; Range 18 - 32 years; 10 males, 14 females). A formal a priori power analysis was not conducted and the sample size of 24 was chosen prior to data collection, based on the sample sizes of similar studies on the psychological effects of action videogames (e.g. Libertus et al. 2017) and studies using global/local processing tasks (e.g. Gerlach and Krumborg 2014; Helton 2008). To avoid discrepancy in previous gaming experience, the criterion for inclusion was being a nonvideo game player (Green and Bavelier 2006), with no more than 5-hours game experience a week in the past 6 months (M_{hours} = 1.96 hrs, SD = 1.58 hrs). All participants reported normal or corrected-to-normal vision. Course credits were awarded for participation. The study was fully approved by the Ethics Committee of Liverpool Hope University.

3.2. Materials

3.2.1. Snapshots of videogames

A greater variety of visual objects are presented in Light Heroes (see A, B, C in Figure 2, e.g. heroes, enemies, etc) compared to Clusterz (see D, E, F in Figure 2), in which only bubbles and several black circles are displayed. In Light Heroes, the 'cognitive contents' of visual objects are also richer than that in Clusterz (for more details of the games, please see Yeh 2015). Strictly speaking, Light Heroes is an 'action-like' (point-and-click, shooter, and role-playing) videogame; which can be differentiated from other first-person and third-person shooting games that have recently been defined as the two main types of action videogames (Bediou et al. 2023; Parong et al. 2021). We chose this 2D simple action-like videogame for the same reason to reduce the complexity of cognitive load and to make better comparison for another 2D non-action videogame, Clusterz.

Forty snapshots of two online videogames were obtained. Snapshots were equated on low-level stimulus properties (size & luminance; Harrison and McCann 2014). Another 40 black blank screens were created for the no-game condition.

3.2.2. Simple reaction time task

A simple reaction time task ensured that participants' visual attention was focused on the centre of the videogame snapshots throughout the videogame images exposure. This task also provides a measure of cognitive load (Brunken et al. 2003). There were 32 trials of the simple reaction time task per condition. Each trial (see Figure 3) started with a blank screen presented for 3000 ms, followed by a central fixation point displayed for 2000ms, followed by a snapshot of the game image (either a snapshot of Light Heroes in AG condition, or of Clusters in NAG condition or a black blank screen in NoG condition) which appeared in the centre of the screen for a duration of at least 3000 ms. During this period, a red fixation-cross appeared at a random time between 1000 and 2000ms at the centre of each game image. Participants were required to press the spacebar on detection of the red-fixation cross and ignore the game image. After a response, both the game image and the red-fixation cross disappeared, followed by a blank screen for 2000ms. Response times (RTs) to the red fixation-cross were collected, as a measure of the cognitive load demanded in each condition (Brunken et al. 2003).

3.2.3. Navon's letter task

Previous studies have used Navon's letter task (1977) to measure attentional breadth (Förster and Higgins 2005; Gable and Harmon-Jones 2008). Following the design of the letter stimuli in the Navon's task used by Förster and Higgins (2005), there were eight letter stimuli in the form of global composite letters, including large letters composed of small letters. As shown in Table 1, there were four *global targets* (Ts made of small Ls and Fs, and Hs made of small Ls and Fs), and four *local* targets (Ls made of Ts and Hs, and Fs made of Ts and Hs).

There were 32 trials of the Navon's letter task in each game condition, with each of the 8 global/local target stimuli presented 4 times in random order. Following completion of each trial in the simple reaction time task, and after a blank screen shown for 2000ms, in each trial of the Navon's letter task (see Figure 3) there appeared a 500 ms fixation point in the centre of the screen. Subsequently a global/local letter stimulus

Figure 2. Screenshot of the videogame play: Light Heroes (A, B, C,) and Clusterz (D, E, F).

appeared and remained visible in the centre of the screen until participants responded by pressing either the target 'T' or target 'H' as rapidly and accurately as possible on a response pad.

Only correct RTs were analysed. Faster responses to the global targets than to the local targets represent a global (broader) attentional breadth, whereas faster responses to the local letters represent a local (narrower) attentional breadth (Gable and Harmon-Jones 2008; Förster and Higgins 2005). To analyse this we calculated a Global-Local Precedence index (Gerlach and Poirel 2018) by calculating the difference in mean RTs to global and local judgements for each game type (i.e. mean RTs for local condition minus mean RTs for global condition).

3.2.4. Self-rating emotion scale

Emotional responses were measured using a self-report scale (Gable and Harmon-Jones 2008; Yeh 2015), after the completion of measuring cognitive performance at the end of each block. At the end of each block, 8 randomly chosen snapshots in each condition were

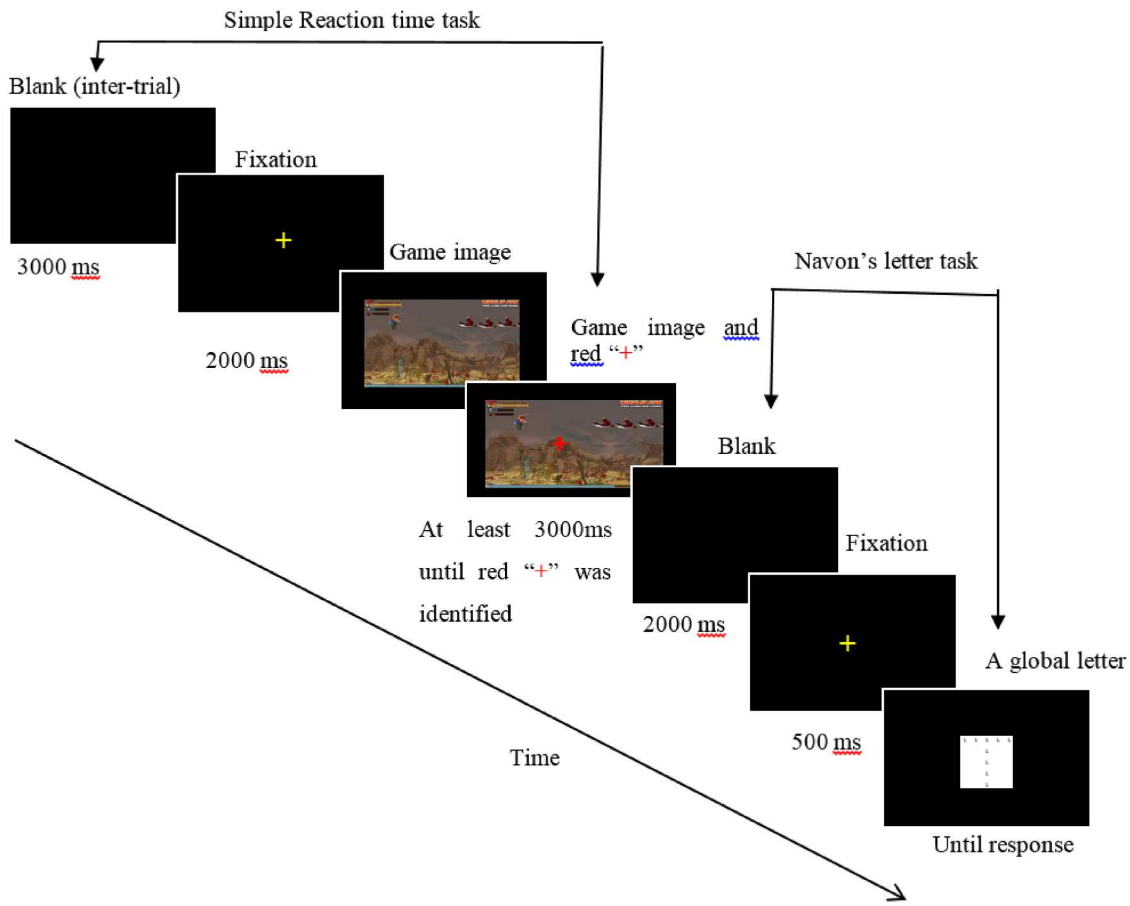

Figure 3. A trial of a simple reaction time task and a Navon's letter task.

presented to remind participants of the images of the games. They were then asked to indicate how they were feeling while seeing these images on a 9-point rating scale: valence (1: very unpleasant; 9: very pleasant), arousal (1: calm; 9: exciting), desire (1: did not desire; 9: really desired; 'While viewing the picture

Table 1. Letter stimuli in the Navon's letter task.

	Target letters			
	T		H	
Global Target	L L L L L L L L L	F F F F F F F F F	L L L L L L L L L L L L L	H H H H H H H H H H H H H
Local Target	T T T T T T T T T	H H H H H H H H H	T T T T T T T T T T T T T	H H H H H H H H H H H H H

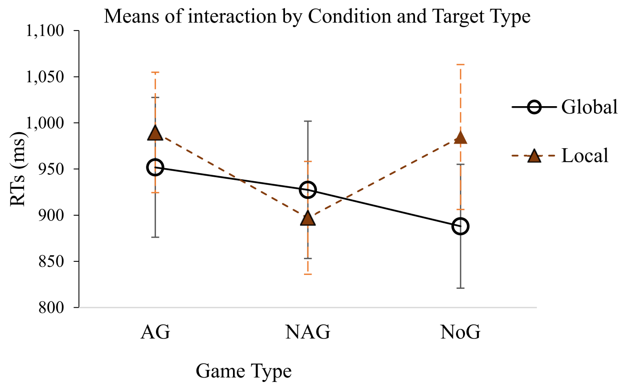

Figure 4. Results from Navon's letter task: Mean responses times of interaction by condition and target type.

how much desire did you feel?'), and stress (1: not stressed; 9: really stressed). For example, participants were asked to indicate to what extent you felt this way while viewing the picture taken from the videogame/ blank screen by circling the number from 1 (very unpleasant) to 9 (very pleasant). Valence and arousal were measured by adapting the Self-Assessment Manikin (Bradley and Lang 1994) which is often used to assess affective reaction in various contexts and emotion studies.

3.2.5. Apparatus

All the above materials including images of videogames, simple reaction time task, Navon's letter task, and self-rating emotional scale were presented on a 17-inch monitor. The viewing distance was approximately 60 cm. The experiment was controlled using E-prime 2.0.

3.3. Procedure

The experiment took place in a quiet room. On arrival, each participant was introduced with a brief description of this study, and provided their consent to partake in this study, following completion of a basic demographic form. Eight practice trials, each including a trial of the simple reaction time task and of the Navon's letter task, were presented for practice. Each participant then moved on to complete all three game conditions respectively (AG, NAG, and NoG) in a randomised order. To ensure an equal number of participants took part in each possible set of game orders, 6 different versions of the study were created in which each version had one of the 6 possible game orders, and each game order was completed by an equal number of participants – ensuring that the number of participants in each version was balanced.

Each game condition included 32 trials which were counterbalanced. Each trial was composed of a trial of the simple reaction time task followed by a trial of the Navon's letter task (See Figure 3). There was an inter-trial interval of 3000 ms before the next trial started. To measure participants' emotional responses, after the completion of all 32 trials in each condition, 8 corresponding game/no game images were presented in a random order to participants to recall their emotional responses and then they indicated their emotional reaction during viewing these images on the self-rating emotional scale before they moved on to the next condition. After they completed all three conditions, participants were debriefed. The total duration of the experiment was approximately 30 minutes.

Data from this study is available on the Open Science Framework (https://osf.io/x258y/).

4. Results

4.1. Simple reaction time task

To examine the differences in cognitive load demanded by different types of visual stimuli in videogames, a one-way repeated measures ANOVA was conducted with the within-subject factor of Game Type (AG, NAG and NoG) with the mean RT across all 32 trials for each condition as the dependent variable. Means and standard deviations of the response times are presented in Table 2. There was a marginally significant main effect of Game Type (F (2, 46) = 3.10, p = .055). Planned contrasts revealed no difference between AG and NAG conditions ($t(23) = .82$, $p = .42$), and no difference between NAG and NoG conditions ($t(23) = 1.464$, $p = .157$). However, RTs in the AG condition were significantly slower than RTs in the NoG condition ($t(23) = 3.0$, $p = .007$). Therefore, Hypothesis 1a was not accepted, however Hypothesis 1b was accepted.

4.2. Navon's letter task

To test the effects of videogame stimuli on attentional breadth, responses times (RTs) on Navon's letter task were analysed (means and standard deviations are presented in Table 3). Accuracy rates were high (between 96.13% and 98.94%) and did not differ between conditions ($F(3.72, 85.59) = 1.95$, $p = .114$). We performed

Table 2. Means and Standard Deviations of Response Times (ms) by condition in the simple reaction time task.

Game type		
AG *M* (*SD*)	NAG *M* (*SD*)	NoG *M* (*SD*)
421.40 (115.20)	410.44 (132.34)	390.23 (108.37)

Notes: AG: Actiongame; NAG: Non-action game; NoG: No game.

Table 3. Means and Standard Deviations of Response Times (ms) by target type and condition (N = 24).

	Game type		
	AG	NAG	NoG
Target type	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Global	951.82 (370.61)	927.43 (364.34)	888.04 (328.60)
Local	989.64 (319.21)	897.13 (299.41)	984.73 (384.48)
GLP	37.82 (126.47)	−30.30 (143.23)	96.69 (166.99)

Note: GLP = Global-Local Precedence Index.

a two-way repeated measures ANOVA with the factors Game Type (AG, NAG and NoG) and Navon Condition (global, local). There was no main effect of Game Type (F(2,46) = 1.58, p = .218) and no main effect of Navon Condition (F(1,23) = 2.62, p = .119). There was a significant interaction between Game Type and Navon Condition (F(2, 46) = 6.20, p = .004; Figure 4). To investigate Hypothesis 2a, RTs in response to the global targets were compared between the action game condition and the no-game condition. A paired t-test found no significant difference (t(23) = 1.66, p = .11). We then compared RTs in response to local targets between the action game condition and the no-game condition. A paired t-test found no significant difference (t(23) = 0.95, p = .93). Hypothesis 2a was therefore accepted.

To examine hypothesis H2b, we computed a Global-Local Precedence index (Gerlach and Poirel 2018), by calculating the difference in mean RTs to global and local judgements for each game type. This is equivalent to the interaction effect reported in the ANOVA above. Positive values on this index indicate faster processing of global compared with local shape information. A one-way within-subjects ANOVA was performed on the Global-Local Precedence index with the factor Game Type (AG, NAG, and NoG). We found a significant main effect of Game Type (F(2,46) = 6.20, p = .004). Planned contrasts revealed that the Global-Local Processing index was lower in the NAG condition (M = −30.3, SD = 143.2) compared to the AG condition (M = 37.8, SD = 126.5) (t(23) = 2.69, p = .013). The Global-Local Processing index was also lower for the NAG condition compared to the No game condition (M = 96.7, SD = 167.0) (t(23) = 3.02, p = .006). These results indicate a narrowed attentional focus in the non-action game, therefore Hypothesis 2b was accepted.

4.3. Emotional responses

To explore emotional responses elicited by visual stimuli in different types of videogame, a within-subject MANOVA was performed (Pillai's trace, V = .49) with game type (AG, NAG, NoG) as the within-subject factor and the self-reported emotional responses (valence, arousal, desire, stress) as the dependant variables. Table 4 shows descriptive statistics of the rating scale responses. There was a significant multivariate effect of game type on the four emotional responses $F(8,\ 88) = 3.60$, $p = .001$, $\eta_p^2 = .25$. Univariate analyses showed there were significant univariate effect among pleasantness: $F(2,\ 46) = 6.20$, $p = .004$, $\eta_p^2 = .21$, arousal: $F(2,\ 46) = 4.22$, $p = .02$, $\eta_p^2 = .16$ and stress: $F(2,\ 46) = 3.90$, $p = .03$, $\eta_p^2 = .15$. However, the levels of desire elicited among three conditions were not significantly different; $F(2,\ 46) = 2.12$, $p = .13$, $\eta_p^2 = .08$. Furthermore, pairwise comparisons showed that, (1) AG stimuli elicited significantly less pleasantness than NAG visual stimuli (p = .003); (2) AG visual stimuli significantly elicited stronger arousal than NoG stimuli (p = .04), but no difference to NAG stimuli (p = 1.00); and (3) stress elicited in AG condition was significantly stronger than in NAG condition (p = .03). H3a (Valence) and H3c (Desire) were not verified, and H3b (Arousal) and H3d (Stress) were partially verified.

Table 4. Means and Standard Deviations of Emotional responses by conditions (n = 24).

	Condition		
	AG	NAG	NoG
Emotional responses	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Valence	4.69^a (1.17)	5.79^b (1.19)	5.26 (1.23)
Arousal	4.23^a (1.83)	4.16 (1.94)	3.40^b (1.64)
Desire	2.40 (1.54)	2.99 (1.86)	2.70 (1.48)
Stress	2.16^a (1.45)	1.69^b (1.10)	1.55 (.77)

Notes: Means with different superscripts in the same row differ significantly at the $p < .05$ level using pairwise comparisons (Bonferroni).

5. Discussion

5.1. Summary of findings

The goal of the present research was to investigate the effects of action and non-action videogame stimuli on cognitive load and attentional breadth, as well as to explore emotional responses to videogame stimuli. Results showed that, contrary to our prediction, the response times in the simple reaction time task after viewing action videogame stimuli were not significantly different to the non-action videogame, whereas, as we predicted, they were slower compared to the no game condition. Further, we showed that the response times in the simple reaction time task did not differ between non-action videogame condition and no game condition.

Results from the Navon's letter task revealed that viewing the action videogame, Light Heroes, did not reduce attentional breadth after the exposure of the red-fixation cross manipulated in the simple reaction time task, resulting in no significant differences in response times to global and local targets in comparison with no game condition. We found a greater global-local precedence effect in the action game compared to the non-action videogame, and a greater global-local precedence effect in the no-game condition compared to the non-action videogame. In terms of emotional responses, viewing Light Heroes visual stimuli were less pleasant than viewing Clusterz, more arousing than NoG condition, more stressful than NAG, and had no difference of desire in relation to viewing Clusterz and NoG conditions.

5.2. Viewing complex action videogame stimuli demanded higher cognitive load

Results in the simple RT task showed that viewing the action videogame, Light Heroes, did not slow responses to the red-fixation cross compared to viewing the non-action videogame, Clusterz. However, the action videogame did decrease RTs in comparison to the no game condition. Furthermore, there were no significant differences in the response times between non-action videogames (Clusterz) and no game condition either.

The above results can be explained by both the cognitive load theory (Chandler and Sweller 1991; Sweller 1988), and gameplay schema. In terms of gameplay schema, visual stimuli in different forms embedded in the videogames may involve different cognitive functions, hence influence subsequent information processing differently (Kalyuga and Plass 2009). And, based on cognitive load theory, the only 'task-relevant information' (i.e. intrinsic cognitive load) designed in the current study was 'pressing the red-fixation cross when it appears' across all three conditions. However, in the Light Heroes visual stimuli there is much more task irrelevant information – the 'extraneous cognitive load' (e.g. the images of enemies and weapons signifying information about the task actions of destroying the enemy and avoiding attacks, the background of the battlefields etc), compared to the non-action videogame stimuli, Clusterz, where the different coloured round bubbles that form different geometric shapes of images are much simpler task irrelevant information.

As hypothesised, the results show that viewing action videogame stimuli was associated with a significantly greater cognitive load than the no game condition. This result supports the notion that the more complex the visual stimuli, the higher demand of cognitive load. Similarly, based on the gameplay schema theory (Lindley and Sennersten 2008), visual stimuli in Light Heroes, such as a fuel or a weapon in a battlefield, may trigger other signals of related cognitive schemas and relevant conceptual information which help with comprehension of the game contexts, and interpretations of the themes. These gameplay schemas may carry different conceptual meanings for higher order cognitive processes. Hence, more cognitive load was needed in the action game condition in relation to the no game condition.

However, our results showed no significant differences in the demand of cognitive load between viewing action and non-action videogame stimuli. This result does not support the notion that the more complex the visual stimuli, the more demand the cognitive load. Conceivably, this may be due to the following reasons. Firstly, the study was likely to have been underpowered and therefore unable to detect small differences in response times between the action and non-action videogames. Alternatively, it is possible that the quantity of the visual stimuli might be an important factor which affects the overall cognitive load. Although it was assumed that images created in Light Heroes may be more complex and may possess more extraneous and germane cognitive load, it can be argued that the number of each type of visual stimuli between two types of games might be similar, resulting in no difference of overall cognitive load between action and non-action videogame condition. Future research might take the quantity of the visual stimuli as a variable into consideration as an important factor which may affect the overall cognitive load. Lastly, it is feasible that the simple reaction time task was not sensitive enough to reflect the cognitive load differences between the two different types of videogame images.

Failure to observe differences between the action and non-action videogame condition could also potentially be due to the fact that static pictures extracted from videogames do not fully reflect the actual cognitive demands imposed whilst gamers dynamically play the game. Unlike other video game research (Dale et al. 2020; Spence and Feng 2010), it could be that the static snapshots of visual stimuli in the current study had significantly removed some lingering effects caused by rapid movements and unexpected appearance of the visual stimuli as well as the interactivity between the players and cognitive demands triggered by different forms of visual stimuli in games. It could also be due to the choice of the action videogame (Light Heroes), which is a simple 2D 'action-like' game. differing from other action video games that used first-person or third-person shooting games. The above reasons are feasible to explain why the result showed that there was no significant difference in cognitive load between the non-action videogame condition and the no-game condition – which is opposed to what is expected from the theoretical assumption. In future studies, other measures such as self-report scales, or psychophysiological measures, may be used to differentiate between cognitive load in these two conditions.

5.3. Effects of viewing videogame stimuli on attentional breadth

Results for the Navon's letter task showed that the response times to global and local letters did not differ between the action game condition and the no-game condition. We also computed a Global-Local Precedence index, by calculating the difference in RTs to global and local judgements for each game type, where more positive values are indicative of faster processing of global compared with local shape information. Results found that the Global-Local precedence index was lower for the non-action videogame compared to the action videogame, and also lower for the non-action videogame compared to the no-game condition. These results indicate that the narrowing effect produced by the presentation of the red-fixation cross on the simple reaction time task in the NAG condition was extended to the subsequent attentional processing in the Navon's letter task. This effect was not present in the action videogame condition. The red-fixation cross in the simple reaction time task is seen as a prime intended to narrow attentional breadth which can be reflected by a lower Global-Local Precedence effect in the NAG condition. These results suggest that the ineffectiveness of the narrowing effect due to the red-fixation cross in the AG condition may be due to the complexity of visual stimuli designed in Light Heroes, which appeared and was displayed in the entire visual field including the peripheral visual fields (e.g. different forms of enemies and weapons), in comparison with the simpler visual design (coloured bubbles) in Clusterz. In other words, the more complex forms of visual stimuli in action videogames may broaden ones' attentional breadth, in comparison to simpler visual designs.

This provides further evidence to support the notion that the action videogame stimuli implicitly affected other internal higher order cognitive processes such as 'cognitive' attentional breadth (Friedman et al. 2003), and that these continued to affect subsequent cognitive processes, i.e. attentional breadth as measured using Navon's letter task. Such higher-order cognitive processes triggered by viewing visual stimuli in action videogames may have inhibited the lower order attentional processes, such as avoiding the narrowing effect of the red-fixation cross in the simple reaction time task and resulting in no subsequent differences in global and local response times in the Navon's letter task. The greater demands of viewing complex action videogame stimuli in working memory capacity may have affected the subsequent attentional processes (Ahmed and de Fockert 2012). The results of the current study provide further evidence that action videogame play may have a broadening effect on visual attentional breadth, in line with results from previous computer game studies (Bediou et al. 2023; Chisholm et al. 2010; Green and Bavelier 2006; West et al. 2008).

5.4. Emotional responses of viewing videogame stimuli and potential effects on cognitive processes

The results regarding emotional responses elicited by viewing images of videogames are somewhat different from the emotional responses elicited by playing actual videogames in the study of Yeh (2015), even though the same action and non-action videogames were used in both studies. The results reported by Yeh (2015) supported the proposed three-dimension model of emotions elicited during videogame play, showing that both types of videogame play elicited similarly high levels of positive affect, coupled with high levels of approach motivation (i.e. desire; Gable and Harmon-Jones 2008, 2010a), yet emotional responses differed in the arousal dimension. However, the current study showed that viewing action videogame stimuli was less pleasant and more stressful than viewing non-action videogame stimuli, and both types of game stimuli did not differ at the level of desire.

To explain this apparent discrepancy, it can be suggested that the complex emotional experiences in all three dimensions elicited during videogame play in Yeh's (2015) study make it difficult to systematically examine the effect of each emotion dimension on cognitive skills (e.g. attentional breadth). Such complexity of emotion may be caused by not only the cognitive mechanisms embedded within the game design (e.g. manipulations of visual attentional breadth, the design of gameplay schemas and goal setting), as well as the interactivity, competitions and the pleasure of control between the game design and the players associated with goal-setting nature of videogame play (Grodal 2000; Vorderer, Klimmt, and Hartmann 2003).

Differently, in the current study, the interactivity between the game contexts and players was removed by only presenting snapshots of videogame images for viewing. This may be the reason for the reduced pleasantness level in the action videogame condition, for no significant differences in desire among all three conditions, and no difference in arousal between action and non-action videogame conditions. This echoes the concept of 'interactivity' embedded within the nature of videogame play that makes videogame play pleasant, fun and desirable (Denis and Jouvelot 2005; Ferguson 2007; Vorderer, Klimmt, and Hartmann 2003). Therefore, the role of visual stimuli designed within games, although also eliciting various forms of emotional responses, may not play a significant role in eliciting pleasantness and desire during videogaming. In fact, by viewing the visual stimuli designed in Light Heroes, such as battlefields, enemies, weapons, fires etc., actually elicited significantly more negative emotions than the viewing images of Clusterz.

The link between emotions elicited by videogame play and cognitive processing has been of growing interest, however, there is a lack of consistent findings on the effects of emotions on cognitive processing and attentional breadth. Research on emotion–cognition literature traditionally, using emotion-elicitation methods such as viewing emotionally-charged pictures or films, and recalling emotional memories, such as Fredrickson and Branigan (2005) and Gasper and Clore (2002) advocate the notion that positive emotions broaden attentional breadth due to a more global and heuristic attentional bias, whereas negative emotions narrow attentional breadth due to less global bias but more local bias.

Conversely, Gable and Harmon-Jones (2008) further differentiated that only those positive emotions which are 'low' in approach motivation (e.g. amusement evoked by viewing a humorous film) would broaden attentional breadth, whereas, those positive emotions 'high' in approach motivation actually narrowed the attentional breadth. Correspondingly, Gable and colleagues (Gable and Harmon-Jones 2010a, 2010b; Harmon-Jones, Gable, and Price 2013) also stated the same pattern of effects of negative emotions vary in the intensity of withdrawal motivation (high: disgust, stress; low: sad). Although the current study found that viewing non-action videogame stimuli elicited positive emotional states, and there was an interaction effect on attentional breadth in the same condition, the current study cannot make direct inference on the emotion-cognitive link.

The current results showing a higher arousal state after viewing the action videogame stimuli and the compensatory effect on the narrowing of attentional breadth may suggest that emotional arousal is a sign of higher cognitive load and cognitive processing. This view partially echoes Yeh's (2015) notion that positive affect coupled with higher arousal may facilitate creative performance. However, viewing action videogame stimuli did not elicit positive affect, which is usually associated with a broadening of attentional/perceptual breadth (Fredrickson and Branigan 2005; Gable and Haidt 2005; Gasper and Clore 2002). This implies that if there would be any effect of emotions elicited after viewing visual stimuli in videogames, then their effects may be overridden by the demands of other cognitive tasks. This notion is in line with results from a fMRI study by Van Dillen, Heslenfeld, and Koole (2009) which showed that the effects of cognitive load induced by another cognitive tasks (such as an arithmetic task) decreased the effects of emotions on the performances of subsequent cognitive tasks which required logical reasoning. However, the study of Van Dillen, Heslenfeld, and Koole (2009) did not consider the cognitive effect of the emotional content within the visual stimuli.

The emotions evoked by viewing videogame visual stimuli may be more complex than other traditional means of emotion elicitation techniques, such as viewing other forms of emotional visual stimuli, or recalling emotional memories. Thus, the result of this study can be better interpreted by the tri-dimensional model of emotions suggested by Yeh (2015), although the present study focused on viewing videogame stimuli rather than playing videogames. Together, it is emphasised that arousal should be an important emotional dimension to the effects on creative processes when investigating the emotional effects of different types of videogames on subsequent creative processes. In her study, in relation to the link between emotion, creativity and videogame play, Yeh (2015) also advocated that the emotional state of positive emotions coupled with high arousal after playing an action videogame may activate a broadened 'cognitive' attentional breadth in comparison to a non-action videogame, however, there was no such evidence as a proof in her study. This may be due to several complex causes, such as the exposure of highly intense visual and audio stimuli, the demand of behavioural responses through eye-hand coordination during playing videogames. Therefore, the current research sort to reduce the complexity of such complex sensational experiences of videogame play in order to explore the link between emotions and attentional breadth by purely focusing on the emotional effect of visual stimuli of videogames on the cognitive processes and excluding other factors such as eye-hand coordination which may increase alertness, arousal and sometimes stress.

5.5. Limitations and implications

The findings of this study imply that visual stimuli and the conceptual information attached to them varying in different types of videogames may trigger effects which affect other internal (top-town) and external (bottom-up) cognitive processes (such as cognitive attentional breadth and visual/perceptual attentional breadth). In affecting top-down cognitive processes, different forms of gameplay schemas related to the stimuli may be triggered. These different forms of cognitive representation may then trigger other cognitive materials and units and other higher cognitive processes; the effect of such can then be transferred and carried over to affect the subsequent cognitive processes (including visual attentional breadth) after the exposure of these visual stimuli designed in game contexts unconsciously without awareness (Shiffrin and Schneider 1977).

A potential shortcoming of the current study was that the types and number of videogame displays were somewhat limited. The comparison between action and non-action videogame visual stimuli was only based on Light Heroes and Cluterz with a contrast that the former was designed with much more complex visual features than the latter. The implication of the result hence is limited to those games which are similar to the ones chosen by the current study. Therefore, future research could further explore effects of visual stimuli designed in other different types of videogames (such as role-playing games). Moreover, here we used a blank screen as the non-game condition, but a more complex type of non-game condition stimulus, such as an emotionally neutral image of nature, could provide a more useful comparison of cognitive load and attentional breadth in relation to the videogame stimuli conditions. Furthermore, it would also be interesting to see whether visual stimuli presented in videogames can achieve greater ecological validity similar to the real game play experiences, although, however, excluding the effect of interactivity. Such studies may help to provide new knowledge of the cognitive mechanisms and emotional responses, which may explain the reasons why that there are many people who like to spend a lot of time viewing others playing videogames (Kaytoue et al. 2012).

Many real-world videogames involve both images and sound, therefore future research could usefully investigate how the effects of videogame stimuli in other modalities (e.g. auditory stimuli) affect perceptual, cognitive, and affective processes. For example, it is known that visual attention is modulated by emotional sounds (Harrison and Davies 2013), therefore the effects of videogames stimuli on visual attention would likely be influenced by accompanying affective auditory stimuli. Furthermore, visual cues can influence auditory attention (Harrison and Woodhouse 2016), therefore future studies could investigate the extent to which different types of visual videogame stimuli influence players' attention to sounds.

Lastly, two points should be noted in relation to the sample used in the study. Firstly, only young adults were recruited as participants, whereas age might be a further factor that could affect cognitive processing and performance during exposure to videogame stimuli. Hence, the interpretation and implication of the current study is limited to young adults, and future research may usefully investigate how age and cognitive development affect cognitive processing of videogames. Secondly, the sample size of 24 participants was relatively small. While the findings provide valuable insights, we cannot rule out that the limited number of participants may affect the generalizability of the results and that any null results were due to the study being underpowered. Future research should aim to replicate this study with a larger sample size to confirm the findings and ensure they are representative of a broader population. A larger sample size would enhance the statistical power of the study and provide more robust evidence for the observed effects.

6. Conclusion

Few research studies to date have sought to examine the effects of videogame play on creativity. Specifically, because creative thinking processes are very complex, to unpick our understanding of the processes, studies are required that focus on specific elements as highlighted in videogame-creativity relevant literature (i.e. cognitive load, attentional breadth and emotions), as well as examining the relationships amongst them.

The present research was original and interdisciplinary: In this study, a conceptual framework was created (see Figure 1) to examine the interplay between the effects of videogames on creativity-related cognitive processes (e.g. cognitive load and attentional breadth), and the role of emotions that are involved in this process. The current study explored the effects of an action videogame and a non-action videogame on cognitive load and attentional breadth which are closely related to creative cognitive processes, and how emotions evoked by the exposure of these different types of videogame stimuli may interfere with such effects. The first theoretical hypothesis on cognitive load was partially supported by the results, supporting the notion that the more complex the videogame visual stimuli the higher the demand for cognitive load. However, the quantity of the visual stimuli, different types of measurements of the cognitive load are worth taking into consideration in future studies to provide further evidence.

Results of the current study also support the second hypothesis that the exposure to the action videogame stimuli has the lingering broadening effect on viewers' attentional breadth in comparison with the non-action videogame condition. The third hypothesis on emotional responses was not completely supported by the results, suggesting that without interactivity designed to cultivate pleasantness and desire during videogame play, viewing action videogame visual stimuli remain to elicit higher arousal and stress in relation to non-action and no game condition.

Overall, the current study showed that visual stimuli used in action and non-action videogames differentially affect creativity-related elements of cognition and emotions. The cognitive representations of the information carried within the visual display are likely to be processed continuously and their effects remain even when other subsequent cognitive tasks are performed, as the mere visual displays of the videogames are found to affect subsequent emotions and cognitive processes. That said, future research should aim to replicate this study with a larger sample size to confirm the findings and ensure they are representative of a broader population.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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