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Cutting, Joe and Iacovides, Ioanna orcid.org/0000-0001-9674-8440 (2022) Learning by doing:Intrinsic Integration directs attention to increase learning in games. Proceedings of the ACM on Human-Computer Interaction. 240. ISSN 2573-0142

https://doi.org/10.1145/3549503

Learning by doing: Intrinsic Integration directs attention to increase learning in games

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Educational games have long been seen as having great potential, but evidence for their effectiveness is mixed, suggesting deficiencies in our theoretical understanding of learning in games and associated design principles. The principle of "Intrinsic integration" of learning content with game mechanics (Hapgood and Ainsworth, 2011) increases learning in educational games, but the theoretical mechanisms behind the principle are unclear, leading to implementation issues. In response, we performed a pre-registered study (n=210) to test possible motivational, cognitive load or attentional mechanisms for moderating learning at an abstract learning task within an educational game similar to Pacman. Learning was higher in the intrinsically integrated version with no significant effects of motivation or cognitive load leading to the conclusion that intrinsic integration increased learning via an attentional mechanism where players only pay attention to features needed for the game task and ignore task-irrelevant information. We discuss theoretical implications for game learning as well as insights for designers of educational games.

CCS Concepts: • **Human-centered computing~Interaction design~Empirical studies in interaction design**

Additional Key Words and Phrases: Intrinsic Integration; educational game; attention; learning

ACM Reference format:
Joe Cutting, Ioanna Iacovides. 2022. Learning by doing: Intrinsic Integration directs attention to increase learning in games. *Proc. ACM Hum.-Comput. Interact,* 6, CHI PLAY, Article 240 (October 2022), 21 pages, https://doi.org/10.1145/336393

1 INTRODUCTION

Games have long been seen as having much to offer education and learning [1-3]. This is reflected in extensive research into games designed for learning [e.g. as reviewed by 4, 5]. However, the evidence for the effectiveness of educational games is mixed, with some reviews [e.g. 6, 7] reporting high levels of effectiveness but others [e.g. 8] finding either no significant effects or insufficient evidence to draw conclusions. These heterogenous findings suggest that our understanding of how to design games for learning is incomplete.

One game design principle that has been demonstrated to increase learning is that of *intrinsic integration* [9, 10] which recommends that material to be learnt should be integrated within the core game mechanics of the game. This principle has become so established that many studies

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[1] This.is work is supported by the Digital Creativity Labs jointly funded by EPSRC/ AHRC/InnovateUK under grant no EP/M023265/1.

2573-0142/2022/10 – Article#240... $15.00
https://doi.org/10.1145/3549503.

which adopt it give little justification for doing so [e.g. 11, 12, 13] or broadly state that it will increase learning and engagement but within little consideration of how this happens. [e.g. 14, 15, 16]. Of the few papers that do consider a mechanism [e.g. 17, 18, 19] all of them posit that intrinsic integration increases motivation, which then increases learning. Given that the title of the seminal intrinsic integration paper [9] starts with "Motivating children to learn effectively", at first sight a motivational mechanism would seem a reasonable assumption. However, the findings of the paper do not actually demonstrate that learning was increased due to changes in motivation. Accordingly, the authors speculated that intrinsic integration may moderate learning via a cognitive mechanism such as attention, memory or cognitive load, but did not investigate further.

Cognitive approaches to learning (e.g. *Cognitive Load Theory* [20]) which consider factors such as attention, memory or cognitive load. have been influential in wider educational contexts and have also been applied to games in a limited fashion [e.g. 21] but are as yet unexplored compared to motivational approaches [see 22 for a review]. The cognitive mechanism of *attentional selection* is known to moderate learning [23-25] and the way games direct attention has been seen as key to a better understanding of game based learning design [26, 27] but to the best of our knowledge, there have been only a few studies [such as 28] looking at attentional effects on learning in games.

Intrinsic integration has been very influential, but when even its originators express uncertainty as to how it works, it is difficult to counter the issues which have been raised with the principle. Most notably, Preist and Jones [29] argue that designing intrinsically integrated game based learning is more difficult than extrinsically motivated "Chocolate Covered Broccoli" [30] learning games that have also been shown to support learning. Others have pointed to tension between intrinsic integration and including sufficient education content [31] as well as limits on pedagogical scope and sustainability [32]. These issues might be easier to solve if we understood the mechanisms behind intrinsic integration. Although a motivational mechanism is considered the default by many authors, alternative mechanisms based on attention or cognitive load are also possible and, if supported by evidence, would open up the possibility of cognitive theories having the same influence on game-based learning as they already do in wider educational contexts.

To further explore whether motivational, attentional or cognitive load mechanisms are active in intrinsic integration, we performed an Open Science [33] study to compare an intrinsically integrated game with a non-integrated game. The games were almost identical apart from the game task which directed players' attention to different visual features of the game. Learning in the integrated game was considerably higher, but motivation and cognitive load were constant. This finding suggests that, in our study, intrinsic integration increased learning by via an attentional mechanism rather than the generally accepted motivational explanation. As well as providing a new theoretical mechanism moderating game learning, our results also offer insights to game designers on how to better facilitate learning within games.

2 RELATED WORK

The design principle of intrinsically integrating learning content and game mechanics was introduced by Habgood, et al. [10]. They saw the principle as an alternative to Malone [34] proposal of integrating the learning content with the game's *fantasy* and described it as having two main components. Firstly, that learning content should be delivered via the most fun part of the game and that secondly that it is embodied "within the structure of the gaming world and the player's interactions with it, providing an external representation of the learning content that is explored through the core mechanics of the gameplay" [10]. They validated the principle with children (ages 7-8) by comparing integrated and non-integrated versions of the maths learning game "Zombie Division" [9]. In the integrated version the core objective of the game (defeating skeletons) required players to perform division, whereas the core objective of the non-integrated version did not require division, but had division tests between levels. Their findings suggested that integration increased both learning and motivation compared with the non-integrated version. Echeverría, et al. [35] extended the principle to tighter levels of integration by applying it to individual "feedback loops between the player and the game", known as "skill atoms" [35]. In each integrated skill atom, success at that part of the game also entails paying attention to and understanding of the appropriate learning concept. Echeverría et al found this approach increased learning, whereas Malone [34]'s recommendation to manipulate the "fantasy" of learning games had no effect on learning.

Intrinsic integration has been very influential with the key papers [9, 10] receiving hundreds of citations, but problems have been raised due the difficulty of designing integrated games and the quantity of educational material that can be taught. Designing integrated learning games requires expertise in both game design and education, with each concept to be taught requiring a custom game design [29]. Compared with task-oriented games, intrinsically integrated games contain less learning material, resulting in a narrower, less sustainable learning experience which end once the player finishes the available material [31, 32]. To address these issues, the logical place to start would be a theoretical rationale for intrinsic integration that describes the mechanisms by which it increases learning in educational games.

Unfortunately, to the best of our knowledge there is no rigorous empirically validated theory of the mechanisms by which intrinsic integration increases learning. Many considerations of intrinsic integration [e.g. 18, 35, 36] assume a motivational mechanism, however the empirical evidence for this is inconclusive and ignores the possibility of attentional or cognitive load-based explanations. Habgood and Ainsworth [9] initially considered a motivational approach by theorizing that intrinsic integration ensures that learning material "rides on the back of the flow"[9] of the game to ensure that the motivation created by the game also applied to the learning content. Motivation in games is often considered via the lens of *Self-Determination Theory* [37] where games increase intrinsic motivation by increasing feelings of competence, autonomy or relatedness. Motivational theories of learning in games [e.g. 38], consider that educational games create sustained engagement, which increases the amount of time that learners spend with the learning material and the depth of their engagement with the material; both which then lead to increases in learning. If this is the case, then learning content need not be closely integrated with gameplay as long as the game motivates the learner sufficiently to spend more time on the learning task. However, in Habgood and Ainsworth [9]'s study, learning was increased in the integrated condition despite learners spending the *same* time on the task as in the non-integrated version. They therefore speculated that rather than a motivational mechanism, intrinsic integration may moderate learning via mechanisms of working memory or attention.

The amount of working memory required to play an educational game is the basis for a second possible mechanism behind intrinsic integration, and is sometimes referred to as *cognitive load*. The influential Cognitive Load Theory (CLT) of Learning [20] considers that cognitive load is a key moderator on whether material can be learnt. It may be that learning is reduced in non-integrated games because they demand [39] higher cognitive load than integrated games. CLT uses the term *intrinsic cognitive load* to refer to the amount of cognitive load required to learn the desired learning material; "intrinsic" here does not refer to intrinsic integration, but the "intrinsic" complexity of the material which, coupled with the learners' prior knowledge, determines how much cognitive load is needed to process it. CLT maintains that learning is dependent on the combination of the intrinsic cognitive load required by the material together with the load required by other irrelevant elements (known as *extraneous* cognitive load) being lower than the working memory capacity of the learner. It is possible that an underlying mechanism behind intrinsic integration is that non-integrated learning games require the game elements and learning material to be processed separately which increase extraneous cognitive load, this then pushes the total load on players over their working memory limits and reduces the amount they can learn.

The third possible mechanism that we will consider by which intrinsic integration could moderates learning in games is *attentional selection* which is acknowledged by theories such as the Cognitive Theory of Game-Based Learning (CTGBL) [21]. CTGBL is based on CLT, but also takes inspiration from the Limited Capacity Model of Mediated Message Processing (LCM) [40]. The LCM posits that we have a limited capacity to process stimulus data from media so only the aspects of the media which we pay attention to are processed and the rest is ignored and so will not be learnt. Following the LCM, the CTGBL considers that learners have a limited capacity to process and retain information as they cannot learn everything on the screen in front of them but only process those elements to which they are paying attention. These elements are then transferred to working memory where they are integrated with existing knowledge and then transferred to long term memory which creates learning. The Task-Attention Theory of Game Based Learning [27] builds on all of these approaches to maintain that specific features of game tasks direct players' attention onto or away from individual game elements. In particular, players direct their attention to features of the game needed to complete the game task, and because of the demands of the gameplay, features not needed for the game task are disattended and effectively ignored. Those elements receiving attentional resources are much more likely to be learnt than those which are unattended [24, 41, 42] resulting in players learning only those features of the game directly needed for the game task. Therefore, it is possible that rather than simply "transferring motivation" from the game to learning content, intrinsic integration may also increase learning due to the way the game task directs players' attention onto the learning content. Integrating content with the game mechanics directs attention onto the content to be learnt which then increases learning of that content and reduces distraction and extraneous cognitive load. If the game task is not integrated with the learning content, then attention may be split between the game and content, increasing extraneous cognitive load and reducing learning. Alternatively, players may just pay attention to the game task and ignore the content which would also reduce learning of that content.

In this study we aimed to determine whether one or a combination of these three mechanisms moderates learning in integrated games. Thus, our central research question is *Does intrinsic integration increase learning via changes in motivation, cognitive load or attention?* To answer this question, we performed an experiment which compared learning between an integrated and a non-integrated game. Our principal focus was attentional mechanisms so our experiment created a severe test of the hypothesis that intrinsic integration can increase learning via attentional focus directed by the game task. However, we also tested for possible motivation and cognitive load mechanisms.

3 EXPERIMENT: HOW INTEGRATION MODERATES LEARNING

This experiment aimed to test the hypothesis that differences in learning due to intrinsic integration are moderated by differences in attentional focus required by the game task rather than motivational effects or differences in cognitive load. To test for an attentional mechanism we made use of the fact that attentional selection can be very tightly focused so that players only process particular aspects of the visual stimulus such as its color *or* its shape, this low-level attentional filtering is known as *feature-based* attentional selection [25, 28]. If intrinsic integration increases learning via attentional mechanisms, then we would expect that learning would be sensitive to very small differences in the closeness of integration reflecting differences in attentional focus. Conversely motivational mechanisms are less likely to be sensitive to small differences in the closeness of integration, as long the player is sufficiently motivated to engage with the learning content.

Intrinsic integration has already been found to be effective with formal classroom learning content [9, 35]. To investigate the mechanisms behind intrinsic integration, and prevent learning measures being confounded by differences in motivation, skill or pre-existing knowledge, we used an artificial learning task that would be sensitive to differences at the level of individual features of the stimulus. In our task, participants were shown 60 different images throughout the course of the game. After the game finished, we measured the number of image shapes they had learnt using a forced-choice recognition test (see Materials). We chose a forced-choice recognition test rather than a recall test as it reduces the chance of confounds due to participants' having varying levels of confidence; there is also evidence that both recognition and recall memory are similarly moderated by attention due to relying on the same underlying mechanism [43, 44].

Our task tested simple rote learning, even though much game-based learning is often concerned with more applied forms of learning such as complicated systems and judgement in complex social situations [e.g. 16, 45]. These different forms of learning are reflected by educational theory which recognizes that learning takes place at number of levels such as Knowledge or Synthesis [E.g. as taxonomized by 46, 47] and it is unlikely that the complexities of each level are fully covered by the retrieval processes we are testing. However, it seems probable that all of these levels are moderated by learners' ability to remember factual information so retrieval learning as tested by our task may moderate many different types of learning and so be relevant to many applications.

This was a between-participants study with two conditions that were very similar, with the only difference being that in the integrated condition the *shapes* of the images were important for the game task whereas in the non-integrated condition the *colors* of the images were important and the shapes were irrelevant for the game task. The main dependent variable was the amount of learning in each game (measured by the number of images recognized afterwards). As the difference between conditions was at the level of attentional features then it is likely that any difference in learning between conditions was due to an attentional mechanism. Secondary dependent variables were players' performance in the game (indicated by their top score) and their level of motivation which was measured using the Enjoyment subscale of the IMI questionnaire [48] (chosen as one of the most commonly used game enjoyment measures [49]). Players' final score was used as a proxy for cognitive load, as the game was cognitively demanding [39] and any additional variation in cognitive load between conditions is likely to impact players' performance and their score at the game. If the integrated condition required less cognitive load this is likely to both increase learning and improve game performance in that condition. The similarity between conditions reduced the likelihood of differences in cognitive load or motivation between conditions, but we measured both of these factors to test whether these mechanisms could have moderated learning. As an exploratory measure we also measured overall game experience using the PXI questionnaire [50]. The full question text for both questionnaires is available in the supplementary materials. Ethical approval for the main study was obtained from the Computer Science departmental ethics committee at the University of York, UK. We pre-registered (see Supplementary Materials) the following hypotheses:

Primary Hypothesis
H1: More learning images will be recognized after the intrinsically integrated condition than the non-integrated condition

Secondary Hypotheses
H2: Motivation (as measured by the IMI questionnaire) in both conditions will be equivalent
H3: Game performance (as measured by top score) in both conditions will be equivalent.

3.1 Participants

A power calculation (see pre-registration in Supplementary Materials) indicated that we should recruit at least 200 valid participants. Our stopping rule was to collect 230 participants and discard all invalid responses; if either condition had less than 100 valid responses, we would then recruit participants one at a time until we had at least 100 in each condition. We recruited 231 participants via the online experiment platform Prolific on 25th January 2022 who were each paid £1.75 for their time. We rejected 21 participants – 8 due to technical issues causing loss of data, 2 due to color-blindness, 8 due to failing an attention check and 3 for pausing for more than 20 seconds during the game. This resulted in 210 participants. Ages ranged from 18-40 (M=30.1). 102 were male, 106 were female and 2 were non-binary.

3.2 Materials

This was an online study that participants completed on their own computers via a browser. It was inspired by Cutting, et al. [28]'s study in which participants played a game containing a set of changing images and attentional focus was then measured by testing their post-game recognition of the images.

The learning content consists of a set of 60 icon images from the *Webdings* character set, and in both game conditions participants play a modified version of *Pacman* [51] (See Figure 1). Unlike the original Pacman there are no power pills which allow the player to eat ghosts. Instead, the Pacman character contains an image as do all the ghosts. Both Pacman and the ghosts also vary in color. Normally if a ghost catches Pacman, then the player loses a life and after losing the 3 lives the game ends. However, if Pacman "matches" the ghost then all of the ghosts die and must return to their home before they can chase Pacman again. In the *integrated* condition, Pacman matches the ghosts if both ghost and Pacman contain the same image, in the *non-integrated* version they match if they are the same color. In this way, the integrated condition integrates the learning content (learning images) with a task needed for the game – eating ghosts. In the non-integrated version players are still looking at the same content images but their shape is not needed for the game task.

Figure 1 The integrated game condition. If Pacman hits a ghost with the same image, then all the ghosts die if the images are different then Pacman dies. The non-integrated game is identical except that the ghosts die if Pacman hits a ghost which is the same color as Pacman (the images are irrelevant for that game).

Every 5 seconds the images in each ghost and Pacman change so that participants are shown 60 different images during the experiment. These are randomly chosen from a set of 90 and shown in a random order. Some images might be more memorable than others, however the images shown in each condition are drawn from the same set so differences in memorability will not be a confound between conditions. After the game, participants are tested on how well they recognize 30 of the images using a forced choice test between an image they have been shown during the game and one they have not seen. An online playable version of the experiment and example video are available via the supplementary materials.

3.3 Results

All data analysis was performed using Jamovi. H1 and the exploratory analysis of PXI data required simple comparisons between two conditions and as the measures produce normal data we used standard independent samples t-tests as well as reporting both Cohen's d effect size and 95% confidence intervals that indicate the power of that effect. H2 and H3 propose that there is no effect between conditions, standard Null-Hypothesis Significance Tests are unable to test for the lack of an effect between conditions so we used the TOST [52] equivalence test which examines whether the hypothesis that there are meaningful effects between conditions can be rejected. The hypotheses and their results are below:

H1: *More learning content will be recognized after the intrinsically integrated condition than the non-integrated condition* was supported with a large effect size; t(208)=5.38, p<.001, d=0.74. (95% CI 0.45-1.03) (See Figure 2).

H2: *Motivation in both conditions will be equivalent* was supported by a TOST test [52] finding that motivation in both conditions were significantly equivalent with a true effect size of less than d=0.5 (ΔL, t(198) = 2.29, p = .011, ΔU, t(198) = -4.95, p < 0.001). A confirmatory t-test showed no significant difference; t(208)=-1.33, p=.185, d=0.18 (95% CI -0.46-0.09) (See Figure 3).

H3: *Game performance in both conditions will be equivalent* was supported by a TOST test [52] found game score in both conditions were significantly equivalent with a true effect size of less than d=0.5 (ΔL, t(204) = 1.68, p = .047, ΔU, t(204) = -5.57, p <0.01). A confirmatory t-test showed no significant difference; t(204)=-1.94, p=.053, d=0.27 (95% CI -0.54-0.006) (See Figure 4).

The exploratory analysis of PXI factors found that only *Autonomy, Progress Feedback* and *Goals and Rules* were significantly different between conditions. All the results are summarized in Table 1. The full set of experimental data before analysis is available, see Supplementary Materials for details.

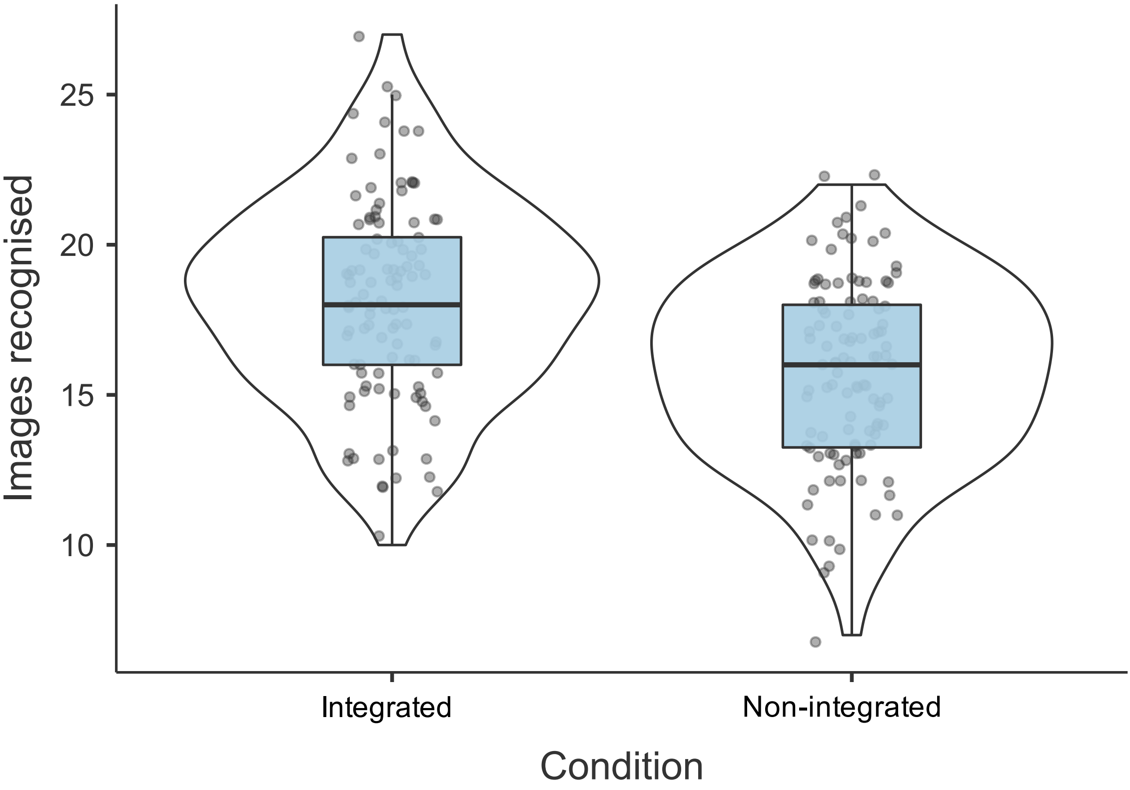

Figure 2 Learning in the integrated game condition was significantly higher than the non-integrated game condition

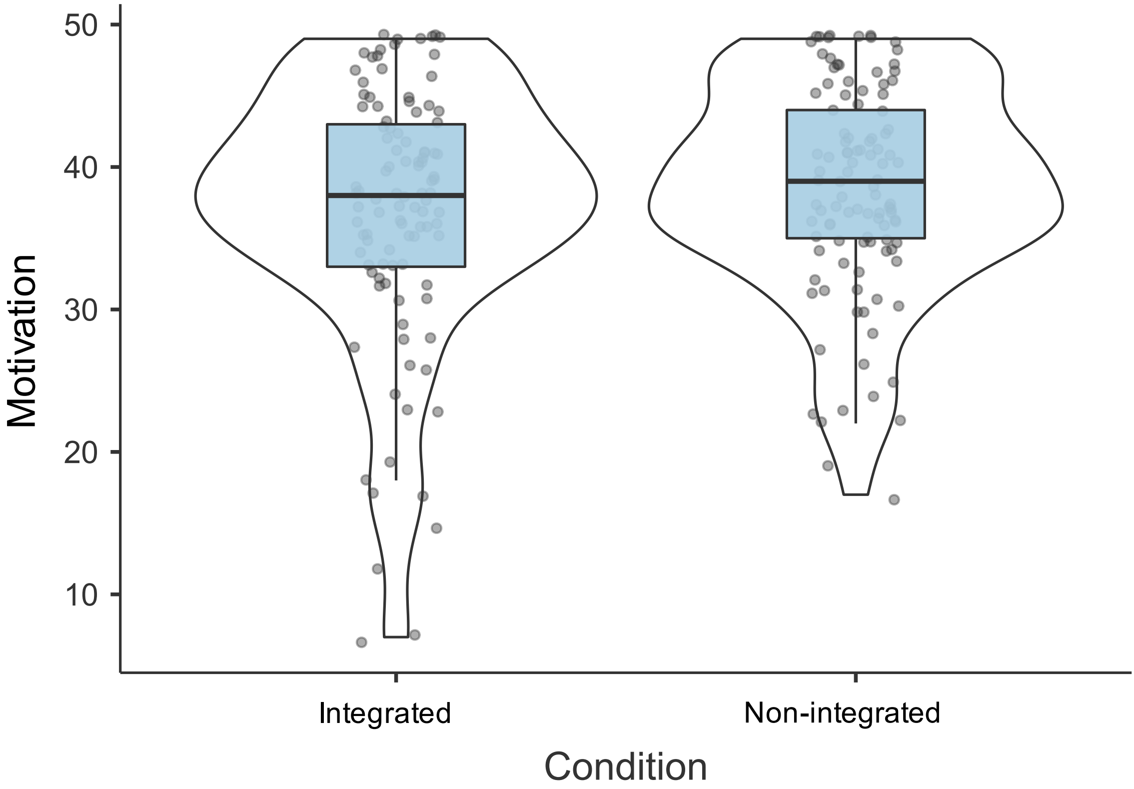

Figure 3 Motivation in both integrated and non-integrated conditions were significantly equivalent

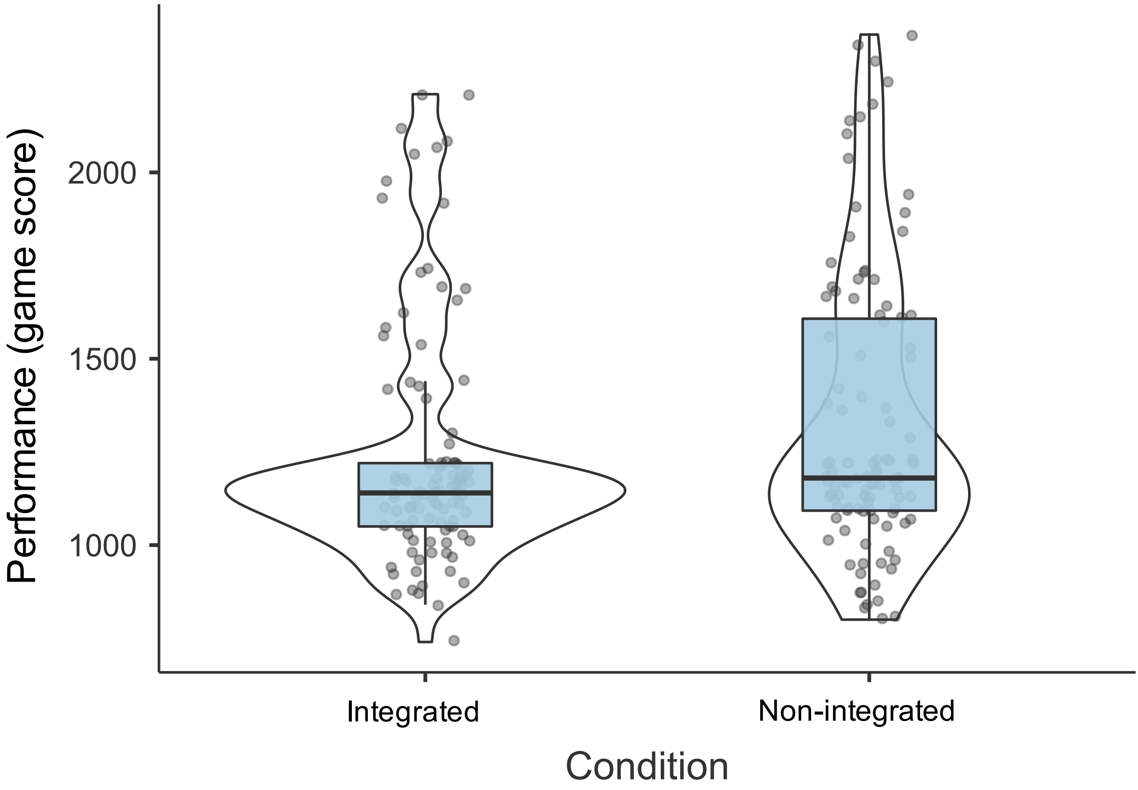

Figure 4 Game performance, which is used a proxy for cognitive load, in both conditions is significantly equivalent

Measure	**Integrated condition Mean (SD)**	**Non-integrated condition Mean (SD)**	**t-test p value**	**Effect Size (Cohen's d)**	**Effect Size 95% CI**
Images recognized	18.2 (3.38)	15.8 (3.11)	<.001*	0.74	0.45, 1.03
Motivation (IMI Enjoyment)	36.8 (9.18)	38.4 (7.43)	.185	0.18	-0.46, 0.09
Game performance (top score)	1237 (323)	1332 (382)	.054	0.27	-0.54, 0.01
PXI factors					
Meaning	11.8 (4.19)	12.0 (4.35)	.709	0.05	-0.32, 0.22
Mastery	12.3 (4.19)	13.0 (3.96)	.196	0.18	-0.45, 0.09
Immersion	12.3 (3.83)	13.0 (3.29)	.063	0.26	-0.53, 0.02
Autonomy	13.1 (4.49)	14.3 (4.00)	.041*	0.28	-0.5, 0.01

Curiosity	13.8 (4.38)	14.3 (4.39)	.415	0.11	-0.38, -0.15
Ease of Control	16.8 (3.16)	17.4 (2.61)	.164	0.19	-0.46, 0.08
Challenge	15.3 (3.46)	15.9 (3.20)	.203	0.18	-0.45, 0.10
Progress Feedback	15.5 (4.00)	16.5 (3.08)	.038*	0.29	-0.56, 0.01
Audiovisual Appeal	14.8 (4.42)	15.9 (3.47)	.052	0.27	-0.54, 0.00
Goals and Rules	18.4 (2.73)	19.1 (2.09)	.029*	0.30	-0.58, 0.03

Table 1 Summary of all data collected. *indicates $p<0.05$. There is a significant difference between conditions in Images recognized but not in Motivation or Game Performance. Of the PXI factors there are significant differences in Autonomy, Progress Feedback and Goals and Rules.

4 DISCUSSION

This experiment aimed to determine an underlying mechanism by which intrinsic integration increases learning. H1 was supported in that learning was higher in the intrinsically integrated game compared to the non-integrated game, as shown by the significantly higher number of images recognized after the integrated game and large effect size between conditions. Both games were almost identical apart from whether the game task required attention to be paid to the color or shape of Pacman and ghosts. This suggests that learning can be moderated by even very small differences in integration between game task and content, in this case at the level of attentional focus on particular visual features of the game graphics.

H2 and H3 were supported as both levels of motivation and game performance between the game conditions were statistically equivalent. This lack of difference was in line with our predictions because both games feature very similar gameplay, apart from the small difference in the game task which directs attention on or away from the learning content. The difference in game performance is not significant, but does tend towards significance (p=0.054) which may suggest, that if our experiment had had higher power, we may have found a significant small effect size of performance being higher in the non-integrated condition. The most likely reason is that the non-integrated condition requires matching colors which requires less intrinsic cognitive load than matching images. Because, non-integrated players have more surplus load available to devote to playing the game they may receive a higher score. Thus, even if the non-integrated condition did require less cognitive load, this is more likely to be an artefact of our experimental manipulation rather than due to differences in integration.

Exploratory analysis of the PXI factors looked for deeper insight into the wider player experience and further support for the main hypotheses. H2 was further supported by the lack of significant difference in the Mastery factor which corresponds to the SDT motivational factor of *Competence*. However, *Autonomy* (another SDT motivation factor) was significantly higher in the non-integrated condition, the opposite direction to that predicted by motivational theories of intrinsic integration which posit that motivation should be higher in the integrated condition. The gameplay in both conditions was identical so the difference in Autonomy was unexpected. One possible explanation is that, as discussed above, players may have found the integrated condition harder to play and misattributed this difference in effort to a difference in autonomy. This misattribution of difficulty may also explain the significant differences in the

PXI factors of Progress Feedback and Goals and Rules despite these design elements being almost identical in both conditions. The most likely reason though is that as this is an exploratory analysis we did not correct for over testing and these significant results may be spurious, if a suitable correction (e.g., Bonferroni) is applied then there are no significant differences between any of the PXI factors.

These results provide significant evidence to answer our main research question of whether the mechanisms by which intrinsic integration increases learning are due to changes in motivation, cognitive load or attention. Both Habgood and Ainsworth [9] and Deterding [36] hypothesize that intrinsic integration is effective because the "flow" from the game "transfers" to the learnt content, increasing motivation which would increase learning through increased time on task. However, in this study, the games were almost identical and there was no difference in motivation or time spent on the task which implies that learning was not increased by a motivational mechanism. The Cognitive Theory of Game Based Learning (CTGBL) [21] posits that levels of cognitive load are important to the effectiveness of learning in games. If levels of cognitive load had varied between conditions, this would have most likely led to a difference in game performance, but game performance was significantly equivalent between conditions, so it is unlikely that differences in learning are mainly due to a cognitive load mechanism. Although, not significant, there was a small effect size difference in performance between conditions, which may indicate very small differences in cognitive load, but this is unlikely to have been the main mechanism for such a large difference in learning. The Task-Attention Theory of Game Based Learning [27] considers that game tasks direct players' attentional focus which then moderates learning. In this study the game task in different conditions directed players to focus their attention on different features of the game. In the intrinsically integrated condition participants directed their attention onto the learning content and which then increased learning. In the non-integrated condition participants needed to direct their gaze onto exactly the same learning content, but because those features were not needed for the game task, players ignored them and they were not processed or learnt. This suggests that attentional focus is an important mechanism by which intrinsic integration increases learning in games. This finding is also consistent with the CTGBL, which despite being primarily concerned with cognitive load also sees attentional selection as a moderating precursor to learning in educational games.

The experiment did not find that intrinsic integration moderates learning via motivation or cognitive load. Despite this, it is likely that attention is only one mechanism by which intrinsic integration can moderate learning, and it is probable that integration can influence both motivation and cognitive load, which in turn may then moderate learning. Non-integrated educational games may reduce motivation due to the "Chocolate Covered Broccoli" effect [30] in which gameplay and content are seen as two competing systems with different goals. This could result in unclear goals and unfocused gameplay which then reduce levels of engagement and motivation [53]. Similarly, unintegrated games may also increase cognitive load demands by requiring learners to process both gameplay and learning content separately, adding to their cognitive load and reducing performance at the game and learning of the content (similar to the "Split-Attention effect" [54]. Although, as we have shown in this study, it is also possible that learners just concentrate on what they see as the main task to be completed (usually the game) and ignore all competing sources of cognitive load.

4.1 Theoretical Implications and Design Insights

The finding that an attentional mechanism moderates learning in intrinsic integration makes a theoretical contribution to our understanding of learning in games and highlights the value of considering cognitive aspects of games alongside existing motivational approaches. We found that attentional selection onto or away from the learning content strongly moderated learning and that this selection is in turn strongly moderated by the low-level characteristics of the game task being performed. Previous motivational approaches to game learning [e.g. 38] have tended to see games as "motivation creators" which may create engagement in learning, whilst ignoring how learning is moderated by the details of the game task being performed. The importance of learning task characteristics is acknowledged by wider educational theories such as *Problem-Based Learning* [55] which stress the importance of learning via professionally relevant tasks and *Constructionism* [56] which posits the importance of learners performing the task of constructing artefacts. Game task features such as rewards and feedback have long been seen as effective ways of keeping learners' attention *onto* the game [57]. Other game task features which have been linked to learning may also have underlying attentional mechanisms. For example, Iacovides, et al. [58] found that "game-play breakdowns" and "breakthroughs" increased learning which may also be due to these events focusing attention onto particular features of the content to be learnt.

Our finding that attentional selection *within* the game moderates learning is predicted by the Task-Attention Theory of Game-Based Learning (Task-Attention Theory for short) [27]. This theory posits that game design features such as *Mechanics, Goals, Uncertainty* and *Rewards* direct players' attention *within* the game and that additional demands [39] on the player such as *Perceptual* and *Cognitive* load further serve to moderate attentional focus. In line with predictions from this theory, our study moderated the *Mechanics* of the game so they were either integrated with the learning content or not, this then directed attention and moderated learning as Task-Attention Theory would predict. Task-Attention Theory is a recent theory which has not yet been extensively tested and the results from this study add valuable empirical support.

In itself, knowing an underlying mechanism behind intrinsic integration does not directly solve the principle's shortcomings such as limitations on the quantity of education material [31] or the difficulty in designing integrated games [29]. However, it does provide new insights into how the design principle works which may aid designers and lead to new approaches. One insight of our findings is that low level characteristics of the game task being performed can strongly moderate learning. Previous motivational approaches to intrinsic integration tend to see games as monolithic motivation creating entities that "transfer" some of their motivation to learning, whilst ignoring how the details of the game task moderate learning. We found that players learnt a lot more if the information was directly relevant to the specifics of the game task they were performing, which suggests that designers of educational games should seek to design game tasks such that the low-level characteristics of the tasks focuses attention onto the material to be learnt.

Another insight from our experiment is that learning was strongly moderated by very subtle feature-based changes in attention within the game. Players in the non-integrated game had to look directly at the learning content, but because the visual features they are looking at are not needed for the game task, then they were ignored and not learnt. Unlike motivation which is seen to "transfer" when learning and gameplay are broadly aligned, demanding gameplay can focus attention very tightly and if the content is outside of that focus, then learning can be reduced substantially. This has the implication that the *degree* of integration between learning content and game task is important with optimum learning happening when they are tightly combined so that the task focuses attention onto only the content to be learnt.

A final insight is on the effect of game genre on learning in games. We found that game task-based attention moderates learning in a fast-moving action game but Cutting, et al. [28] also found the same attentional selection effect on learning with slow moving "self-paced" games with no requirement for fast reactions or decisions. They concluded that game tasks direct attention by the formation of an "attentional set" [59] of task relevant features which is formed by the initial instructions and feedback that players receive while learning the game. Although both action and self-paced puzzle games focus attention onto features needed for the game task, it is likely that the increased demands and time limits of action games create more sustained attentional focus. This is supported by Cutting and Cairns [60]'s finding that less immersive games create less sustained attentional focus, with attention more likely to wander onto irrelevant features. However, an issue with using action games for learning is that the features needed to perform the game task are typically spatial attributes such as the position and movement of elements rather than their symbolic and visual details. This makes it difficult to integrate learning content tightly with the game task because learning content typically consists of images and symbols and the relationships between them, which tend to be abstract rather than related to spatial attributes. The game tasks of slower moving puzzle and strategy games generally require focus on the visuals and abstract relationships between game elements which makes them easier to integrate with academic learning content. Of course, some game learning content such as learning to drive or fly *is* concerned with the spatial relationships between elements making it easier to integrate an action game task with the learning content. But even in "realistic" simulation games, optimum learning will occur when the game task is designed to focus attention on the most critical learning material.

4.2 Limitations and Future Work

There are a number of limitations of this study which may point the way to future work. One potential limitation is that in order to create a tightly controlled experiment we used an artificial image learning task rather than "real" learning content. Therefore, a fruitful area of future work could be to investigate attentional moderation of learning of more applied and complex learning content. Games containing complex content models are not always successful at teaching those models [61]. It could be that learning complex models is moderated by game task-directed attention which requires attention not only to be paid to all the features of the model and the relationships between them, but that attentional focus needs to paid in the correct order to provide scaffolding [62] to players' learning.

Another possible limitation is that this study was done on adults who played the game online rather than a more prolonged intervention with children in a classroom setting. However, online game experiments have proved their effectiveness [e.g. 63, 64] and online learning games for adults are important in areas such as higher education and training [65] which has stimulated efforts to improve game-based learning aimed at adults [e.g 66]. Online studies are thus more ecologically valid for this type of learning than classroom-based investigations. Another advantage of online studies is that they allow larger number of participants to recruited making experiments more rigorous and likely to be replicated [67]. In this study we investigated feature-based attentional moderation of learning but it is likely that game learning is also moderated by covert and spatial attention as well as the motivational and cognitive load mechanisms that we also considered. These mechanisms may also have smaller effect sizes that our study lacked sufficient power to measure. Similarly, our study used a short (5 minute) game and tested learning immediately afterwards which may not reflect real learning experiences. Future work could seek to replicate our results with children in a classroom setting with longer games and a longer interval before testing, or could use similar online studies, with considerably more participants, to perform higher powered investigations of these mechanisms and how they relate to each other.

A final issue with this study is that even with modifications, the task in a game such as *Pacman* is not that closely integrated with the task of learning images. As discussed previously, even though in the integrated version participants are paying attention to the images they are also allocating mental resources to the other spatial aspects of the game such as the location of the ghosts. In the context of a study investigating attentional effects on learning our experiment presented a more severe test of our hypothesis than using a slower moving, less demanding game. However, if our primary purpose was to design a game to promote learning of images then for maximum intrinsic integration, we would choose a game where the core gameplay revolved around learning images with minimal other attentional demands; for example, the card game *Memory (*also known as *Pairs* or *Pelmanism).*

5 CONCLUSIONS

We aimed to determine an underlying mechanism by which intrinsic integration of gameplay and content increases learning. Previous work has assumed that this mechanism was solely due to motivation, despite the possibility of cognitive mechanisms such as attention or cognitive load. Our study found that learning was considerably higher in an integrated game than a non-integrated game with no difference between the games in motivation or cognitive load. The only difference between games was that the integrated game directed players' attention onto the learning material, while the non-integrated game, although containing the same material, did not direct players' attention towards it as part of the game task. Thus, we concluded that intrinsically integrating the content and gameplay increased learning by directing players' attentional focus onto the learning content that would otherwise be ignored due to the demands of the game.

This evidence of an attentional mechanism that moderates learning in intrinsic integration makes a theoretical contribution to our understanding of *how* the principle works which is in contrast to previous motivation-based theories. Our results provide support for existing theories such as the Cognitive Theory of Game Based Learning and the Task-Attention Theory of Game Learning which consider attentional moderation of learning in games. Our findings also provide insights into the effective design of educational games, particularly the use of intrinsic integration as a design principle. These insights mainly center around the importance of the *task* that players are performing and how it directs their attention *within* the game and onto or away from the content to be learnt which will then moderate learning. Future advances in our theoretical understanding of learning in games could create similar design insights which have the potential to increase the overall effectiveness of educational games thus allow games to fulfil their potential as a key part of learning in both online and classroom contexts.

Supplementary Materials

An online playable version of the experimental game which does not save data is available at: http://www.joecutting.com/demos/Pacman. A video of the experiment ("ExperimentVideo.mp4") and all the data collected during the experiment ("ExperimentalData.xlsx") are available as supplementary files. The project has an OSF repository at https://osf.io/hrjxe/ containing the pre-registration, power calculation, questionnaire items and all source code needed to run the experiment.

Acknowledgements

This work was supported by the Digital Creativity Labs jointly funded by EPSRC/ AHRC/InnovateUK under grant no EP/M023265/1.

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Received: February 2022, Revised: June 2022, Accepted: July 2022.