

## How Can Experimental Psychology Inform Game Design?

David Brodbeck

Department of Psychology Algoma University  
Department of Psychology Laurentian University

Jeb Havens

1st Playable Productions

What makes a player keep coming back to a game? Why are some games hits and others misses? Are there guiding principles, even scientific ones that can help us design better games? We hope to answer these questions, or at least provide the beginnings of answers in this paper. In our view, while design is certainly an art, there are scientific principles that can be applied to this artistic process. Those principles come out of the field of experimental psychology.

### Learning Theory

Learning Theory is, perhaps, the most studied (some may say over studied) area of experimental psychology. Let us begin with a review of a few basic concepts in Learning Theory. *Acquisition* is the phase where the subject learns the task. *Asymptote* is the phase where the subject is responding perfectly, i.e., he or she cannot perform any better (though may be able to learn still, more on that later). *Extinction* occurs when the contingencies (e.g. stimulus response, or behaviour and reward) are no longer active. *Spontaneous recovery* happens when, after extinction, the subject, when presented with the experimental setup, responds as if he or she was back in acquisition, somewhere near asymptote. The point here is that even though the subject has learned that the contingencies are no longer valid, he or she will still respond as if they are. The subject then reaches asymptote much more quickly than before. Hermann Ebbinghaus (1885) originally discovered this quick relearning in the latter half of the 19<sup>th</sup> century.

Why is any of this important? Well besides being fodder for excellent exam questions for students in learning classes

these phases of the learning curve are universal. It does not matter if you are a sea slug (Castellucci, Pnkster, Kufgermann & Kandel, 1970) or a human (Ebbinghaus, 1885), such things apply. A learning curve that is too gradual may frustrate the learner, whereas a learning curve that is too steep (contrary to popular use of the term) may be too easy.

Designers are all well aware of this sort of thing and design games with this in mind, explicitly or implicitly. The point, from a design perspective, is to provide the player with an environment in which their behavior is recognized and rewarded in a pattern that encourages the player to continue their exploration and/or mastery of the game system. What we want is for people to continue to play a game; we want the pigeon to peck at the key if you will. Though, ideally, the pecking itself becomes the satisfying act, rather than just the reward.

For the most part games operate in an environment where behaviour is rewarded in some way. This brings to mind BF Skinner's work on reinforcement (Ferrster and Skinner, 1957). A reinforcer is some event that leads to an increase in behaviour (Ferrestter and Skinner, 1957). While that definition is circular, we now know that there is a reinforcement circuit in the brain, the mesolimbic dopamine system (McKim, 2002) that is 'turned on' when something feels good. This circuit is operated when we eat a good meal, laugh or, reach a save point in a game.

One might think that the best way to maintain behaviour is to give reinforcement on a constant schedule, say after every incidence of the behaviour. However, this simply does not work very well. The best

way to maintain behaviour is through intermittent and unpredictable reinforcement. So after a number of occurrences of the desired behaviour the reinforcer (again say a save point) is given. One would typically vary the ratio of reinforcers to behaviour (a variable ratio schedule) and work the subject up to this level. So you start out early on with rather common reinforcement and make it less common as time goes by. There is a possible issue here of what is called 'ratio strain'. Subjects will stop responding if reinforcement is too rare. From the subject's perspective this makes complete sense of course, as the extinction phase of learning (again from the subject's perspective) seems to be taking place. In that case all that is needed is a couple of reinforcers to bring the subject back (spontaneous recover) to responding.

It seems that such a set of contingencies could be built into a game. It could be implemented as follows. We know how long the player has been playing and when the last time that a reinforcer was given (say some item, or some body amour, or a save point) If the player has put the game away for a while he or she could be reinforced quickly for picking the game back up, and then the ratio of reinforcers could be pulled out back to a level that would maintain behaviour. The ratio of reinforcers to behaviour that the player stopped at would also be known. We could easily bring the player back up to a level *lower* than that. This would sort of pull the player back in to the game.

Another method of providing such intermittent reward is to work with the chaotic nature of a game system. Chaotic systems, though completely deterministic, are non-predictable in the long term and only semi-predictable in the short term. A game system that employs a number of simple, yet richly interacting, components will generate emergent behaviors and strategies. Because of the non-predictable nature of these strategies, the player is not guaranteed to obtain the sought reward every single time. Instead, a small difference

in any number of factors could lead to a partial or missed reward (think butterfly effect). Whereas normally, not providing the player with the anticipated reward would cause player frustration, in the case of well-designed emergent behavior, the reasons for failure are completely transparent and retroactively explainable. Instead of frustration, this type of non-predictable reward schedule drives the player even harder to learn from their previous missteps and try again.

An intermittent reward schedule also ensures that the game flow remains surprising and uncertain. Uncertainty is a key element of the player experience of a game. A game in which the exact path to completion is fully known is no longer a game (or at least not a fun one), and loses the "magic" that arises from navigating an uncertain possibility space.

We want people to come back to games, and we want to reduce the likelihood that people will put down a game and never come back. Of course, learning by performing the behaviour required for a task is the best way to learn. However, it is also possible to learn by observing. Typically players are observing the action and playing simultaneously. That said, one can also learn by pure observation.

Mattar and Gribble (2005) had subjects watch an expert use a robotic arm. They also had a control group watch a model perform incorrect movements for controlling the arm. Subjects that watched the expert perform the task actually performed better than those that did not watch or that watched the incorrect video. This was without any training or directed studying.

Mattar and Gribble's (2005) results may be telling when it comes to multiplayer gaming. Often times in games like *Counterstrike*, *Ghost Recon* or *Rainbow Six*, your character dies and you are then put into 'God mode' where you can watch all of the action or follow a single player. The problem here is that there is no real reinforcement for watching others play. If the (eliminated) player could somehow be

reinforced for watching the rest of the game he or she could improve, and improve without any conscious awareness that they are even learning anything.

### Divided Attention

Sam Fisher is crouched behind a guard, the light meter says it is totally dark, Lambert is talking in his ear giving him new instructions, he checks his inventory, two flash bangs and his pistol, there is another guard looking right at him, wait until he turns away, then grab the first guard and interrogate him, knock the guard out and hide the body in the shadows.

This describes a lot of what great action games are all about; you are processing many different things at once. In psychology this is called divided attention. Attention is the allocation of perceptual resources and we only have a finite amount of it. We selectively divide attention between tasks. This has been studied extensively using dichotic listening. In a dichotic listening paradigm the subject hears two different messages, one in the left ear and one in the right ear. The task is to shadow one ear, i.e., repeat what is said in one ear and ignore the other (Kimura, 1967). The subject invariably learns, in very short order, to ignore the other ear. Indeed, one does not notice a change in language from one ear to the other (reference). That said, the other ear is constantly monitored but without the conscious awareness of the listener. If the subject's name is said in the unattended ear, or a word like 'danger' or 'fire' is heard attention shifts to that other ear. The same thing happens if the story shifts from the attended to the unattended ear. For a few seconds the subject shadows the to be ignored ear, before going back to the target ear.

Subjects can learn things about what is happening in the unattended ear, without knowing anything about the content. Szostalo (1998) had subjects listen to a narrative in one ear and ignore the other. While doing this they also had to attend to a computer monitor. When the monitor

flashed they were to push the spacebar as quickly as possible. Now in one group these flashes were preceded .5 sec earlier with the word 'President' in the unattended ear. Of course in the control group there was no contingency between the word president and the flash. Subjects in the control group showed absolutely no improvement in reaction time during the 13 minute experiment. However, a marked improvement in reaction time was shown in the experimental group. The key point is that in Szostalo's (1998) experiment, subjects were asked if they could say anything about the unattended ear. None of the 36 participants noticed anything about the unattended passage, save one that said 'I think that was Dr. Brodbeck reading in my right ear.' (This is typical, people recognize voices, tonal qualities but NOT content).

Well very few people here at Future Play are designing audio games now are they? However, the same divided attention phenomena happen with video. Becklen and Cervone (1983) had subjects watch a basketball game. They were asked to count how many times the ball changed hands. Subjects were motivated with a possible reward at the end of the experiment (money if they got the right number of ball exchanges). Subjects paid such close *visual* attention to the game that they did not notice a person walk right through the middle of the video of the game carrying an umbrella.

When designing a game, it is important to keep in mind the nature of human attention – our perceptual systems can only handle so much input. The player will have a very limited and specific attentional focus at any given time. The player can only attend explicitly and consciously to a small subset of what their senses are being exposed to. Where will the player be looking at any given moment? What sounds are they listening to? Practically speaking, how do you know which parts of the game to throw your money into polishing and refining, and which aspects of the game aren't even going to register in the player.

To begin to answer questions like these, it is important to model the game system not in terms of the inputs and outputs of the computer, but in terms of the inputs and outputs of the player's mind. The game takes place inside the player's mind – the game that you build with software and hardware is providing the answers to questions that arise in the player's mental version of the game: What will happen if I try this? Push here? Shoot that? Build two of these? A well-designed game should provide reasonably obvious ways to ask those questions through action and/or directed attention, and should (perhaps more importantly) provide clear and consistent answers. Unfortunately, there is no way of simply transferring an entire game state or set of systems into the player's brain all at once. The interaction between brain-model and computer model is a dynamic one that has a very narrow channel of information transfer. Remember, attention and conscious perception are active processes, not passive ones. To understand what parts of your game a player will be attending to, you have to understand what the player will be asking your game and where they expect the answers to come from.

Another conclusion from the attention studies results is that designers can easily tweak a game to make it more or less difficult by making more input, or input from many sources occur. As well, one could play with the shift of attention from attended to unattended stream of information in order to make a certain part of a game more difficult.

The Szostalo (1998) data taken together with the Becklen and Cervone (1983) experiment suggest that designers may be able to teach players how to solve a problem without the player even knowing that he or she had been taught. Hints could be given in essence. This sort of tweak could be very subtle, almost unnoticeable to the player. This would make easier difficulty settings not seem on the surface to be that much easier than the expert levels. This could perhaps provide a better experience for the player. One can also

imagine teaching the player some contingencies early on and then turning off this implicit tutor. The quick completion of an early level that involved these implicit tutors would also be reinforcing for the player, thus leading to more play.

The most powerful learning that takes place while playing a game is Implicit – the learning of patterns that takes place subconsciously while playing a game. This sort of learning is not about the player asking questions, it is about absorbing and applying patterns. It is more about “How” than it is about “What”. What are the underlying patterns to the gameplay? Many of these patterns are similar between games of the same genre or style, making it easier for experts of a given game genre to pick up and master a different game of the same type. It is important to understand and define the implicit knowledge of a game's audience, since it will inform how much and what types of implicit knowledge can be relied on from the start versus the patterns that need to be taught.

Implicit learning can be encouraged in a game by building consistent associations in the player's mind regarding the various game components, focusing especially on things that are directly perceived, such as visual similarities or functional similarities. Any similarities between components should be meaningful enough to form implicit associations that hold true in the larger context of the game. These associations, which often manifest in players as “gut” feelings or an undefined “sense” of how the game world works, allow the player to skillfully handle new situations by combining implicit knowledge from previous situations. As an additional bonus, because the learning was implicit, the player receives an even greater sense of achievement for seemingly figuring it out completely on their own.

## Memory

### *Short Term Memory*

A common model of human memory is the Atkinson and Shiffrin (1968) model. In this model we have a sensory register, which contains unprocessed sensory information that decays very quickly, indeed, much less than a second. Long Term Memory (LTM), that is essentially limitless and Short Term Memory (STM) has a finite capacity, and lasts a very short period of time (a couple of seconds) without some processing round out their model. (This processing may be as simple as rehearsal, so repeating a phone number to yourself as you pull out your cell phone in order to keep the number in mind is an example).

The capacity limit on STM is  $7 \pm 2$ . One may ask  $7 \pm 2$  what? Well psychologists have come up with the term 'chunk.' A chunk is the smallest unit that can be processed. Experts can work with bigger chunks than novices. Indeed experts can remember more than novices can. If a chess expert is shown a chessboard with the various pieces in play he or she can remember their positions better than an intermediate level player (Chase & Simon, 1973). The difference between experts and non-experts has quite a bit to do with how they chunk material. At this point in our lives we are all phone number experts, usually using only two slots for phone numbers, the exchange (first three numbers) and the other four numbers. If we are learning a new number we already can chunk the exchange because we know most of the exchanges where we live. However, when one moves to a new city there are many new exchanges to learn, and we often take up all seven slots in STM, until we become experts. So there is a limit on perception as we have seen in the previous section, but there is also a limit on STM. How can this inform game design?

A successful game must always provide ways to become an expert. While a designer can usually require expertise just by making a game harder (shortening a time limit, adding more enemies, etc.), more meaningful guidance of expertise comes from understanding chunking.

Understanding which aspects of the game can, with experience, be chunked together into a single concept will allow you to guide the player more specifically towards expertise. Usually, the process of chunking involves "zooming out" – what was previously a series of separate actions or decisions now becomes a single unit, handled cognitively in a single decision.

Often, the various components of a game have specifically patterned interactions, but those interaction patterns are not obvious when first encountering them. Through repeated experience and discovery, patterns are learned and the components and experiences collapse into chunks. This process allows the player to slowly understand the chaotic game system at a series of higher and higher levels, like a fractal, each time seeing something new yet familiar, and each time feeling the renewed sense of mastery and broader perspective that comes from gaining expertise.

During the early stages of a game we cannot throw too much at the player, perhaps four or five bits of information at a time. It must be kept in mind that if a new item enters STM it kicks out an old one. (Try yelling out random numbers to a friend that is repeating a phone number while pulling out his or her cell phone). Once the player has more experience we can present more information to the player, as those early, say five items, now only would take up one slot in STM (i.e., what used to take up five slots in STM now becomes one chunk and takes up only one slot). Now the question of what makes a chunk in a given game would come with beta testing. It would be hard *a priori* to know exactly what a chunk is.

A more recent idea about STM involves not only renaming it as "working memory" but dividing working memory into two modules, the phonological loop and the visuo spatial sketchpad (Baddely & Hitch, 1974). These modules share data through a central executive, but they deal with separate items (hence the names). We can then send verbal information to a player and it will not interfere with spatial information

(route planning, that sort of thing). So here we may be able to push a player more than one would expect if some of the data we are presenting are visual and others are verbal.

### *Long Term Memory*

Long Term Memory or LTM is essentially limitless and is often divided up into different systems such as episodic and semantic (Tulving, 1972). Episodic memory is self referential and conscious, while semantic memory contains facts about the world and is largely unconscious.

We tend to remember things better if we process them deeply. This involves thinking about the meaning of the item rather than just its surface structure. So if you are studying a list of words and counting the number of vowels you will not remember the words nearly as well as if you had to rate how pleasant the words are. This Levels of Processing approach ( Craik and Lockhard, 1972) is still very useful today. Indeed the paper just cited is the most cited paper in all of cognitive psychology. With this knowledge we can make items more or less memorable simply by forcing players to process certain items more deeply.

Much of the memorial work our cognitive systems do is implicit. We are not aware we that are learning anything, or are remembering anything. The Szostalo (1998) experiment discussed above is clearly one involving implicit memory. The wonderful thing about implicit memory is that, unlike explicit memory, it hardly decays (Tulving Schacter and Stark, 1983). It even seems to obey different laws than explicit memory, for example the levels of processing effect does not really show up in implicit memory (Challis and Brodbeck, 1992). Implicit learning is evident in play when the player eventually learns to use a controller and does not have to consciously process what button he or she is pressing. This of course happens in any motor task (once you learn to ride a bike you never forget, that sort of thing). How though, can designers take advantage of implicit memory?

Perhaps hints could be dropped during earlier levels. A cheat code could be printed somewhere on a wall of a level or some such thing

### *False Memories*

Our memories are far from perfect. Basically the human cognitive system fills in gaps when we do not know the correct answer or cannot remember something. For example if I gave you the list of words ‘prick, pin, haystack, knitting, phonograph’ and then asked you later if the word needle was on the list you would probably say it was. Now of course needle *should* be on that list. About 40 percent of people will report that they remember the word needle having been on the study list. (Roediger & McDermott, 1995). Indeed, these false memories seem to be served by somewhat different systems and follow different rules than real memories (Castellani & Brodbeck, 2006). How can the designer use this to his or her advantage?

Now and then it may be useful to lead the player astray. This is an easy way to do it: Implant a false memory in the player. The great thing here is that not everyone will have this false memory. This leads to different experiences for different players.

## **Conclusion**

How can experimental psychology help game design? Through the application of some of the principles we have outlined today it seems to us that designers can make games that are more playable, that players want to return to and that are much more deep than many games currently are. The application of these ideas, and others, does not take away from the creative or artistic process of game design. Indeed, we would argue that it enhances it. Designers can make better games, beta-testing time can be reduced and players can have a more immersive and enjoyable experience if some of these ideas are applied.

While the medium of today's commercial games is typically a computer of some sort, games and play behavior have been around since the origins of social animals. While technology has been the driving force (or at least the most visible force) behind games over the past half century, this represents less than 1% of the total history of games in human culture. The true unifying element to games has always been the player - the human mind - and the enjoyable experience of play. In this light, it seems only natural that in order to achieve a richer (and more fruitful) understanding of game design, we have to look to the people, not to the technology. One of the crucial tools to understanding a player's mental experience of a complex system is experimental psychology, which can provide us practical ways to explore the limits and capabilities of the mind's major systems, such as attention, perception, consciousness, learning, and memory.

#### Acknowledgements

DRB is supported by a Discovery grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) and by the Algoma University Travel and Research fund. We thank Isabelle Michaud for comments on the manuscript.

Correspondence should be sent to David R. Brodbeck, Department of Psychology, Algoma University, 1520 Queen Street E, Sault Ste. Marie, ON, P6A 2G4 tel: (705) 949-2301 (x4336). E-Mail: dave.brodbeck@algomau.ca

#### References

- Atkinson, R. C. and Shiffrin, R. M. (1968). Human memory: A proposed system and its control mechanisms. *In R. C. Atkinson R. M. Shiffrin and K. W. Spence (Eds.) The Psychology of Learning and Motivation*. New York: Academic Press.
- Baddeley, A. D. and Hitch, G. J. (1974). Working memory. *In G. A. Bower (Ed) Recent Advances in Learning and Motivation*. New York: Academic Press.
- Becklen, R. and Cervone, D. (1983). Selective looking and the noticing of unexpected events. *Memory and Cognition*, 11, 601-608.
- Catellani, T. and Brodbeck, D. R. (2005). *Levels of processing in explicit and implicit memory tests of false memorie*. Manuscript in Preparation.
- Castellucci, V., Pnkster, H., Kufgermann, I. and Kandel, E. R. (1970) Acquisition and Retention of Long-Term Habituation in Aplysia: Correlation of Behavioral and Cellular Processes. *Science*, 167, 1745-1748.
- Challis, B. H., and Brodbeck, D. R. (1992). Levels of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 18, 595-607.
- Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, 4, 55-61.
- Craik, F. I. M. and Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*. 11, 671 684.
- Ebbinghaus, H. (1885). *Memory: A contribution to experimental psychology*. New York: Columbia Teachers' College.
- Ferrster, C. B. and Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.
- Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. *Cortex*, 3, 163-168.
- Mattar, A. G. and Gribble, P. L. (2005). Motor learning by observation. *Neuron*, 46, 53-60.
- McKim, W. A. (2002). *Drugs and behavior: An introduction to behavioral pharmacology*. Upper Saddle River, NJ: Prentice Hall.
- Roediger, H. L., & McDermott, B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 803-814.

Szostalo, M. (1998). *Implicit memory in a dichotic listening task*. Unpublished Bachelor's Thesis, Algoma University: Department of Psychology.

Tulving, E. (1972). Episodic and semantic memory. *Organization of Memory*. New York: Academic Press.

Tulving, E., Schacter, D. and Stark, H. (1982). Priming effects in word fragment completion are independent of recognition effects. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 8, 336-342.