Alert Hockey: An Endogenous Learning Game

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Abstract

We describe a video game designed with a subtle and implicit learning mechanism that tracks aggressive and negligent play then uses this data to reduce players abilities and their chance of winning against the computer. By converging the goals of game play with learning we argue the experience produced is both endogenous and outcome oriented. Sixty two participants between 12 and 14 years old played the game at least 15 times each. Both aggressive play and negligence measures were reduced during the study $(F(2, 40) = 10.589, p = 0.0002)$. Implicit learning mechanisms like this have potential to provide specific learning outcomes at little expense to the enjoyment of interactive gameplay.

Introduction

Head injuries in hockey players continue to receive considerable media attention though the main focus remains on high profile professional players. Similarly, while the medical community (both clinical and research) has paid increased attention to the problem of sports-related concussion, this has also almost been exclusively with respect to elite hockey players (Aubrey et al., 2002). Extrapolating from the incidence rate in elite players, one might expect with over 31,000 teams registered with Hockey Canada, and over 30,000 with USA Hockey, well over 43,000 concussions occur annually in youth hockey alone. This, however, represents only a subset of the total number of concussions to youth. In the United States it has been estimated that more than 1 million children sustain a traumatic brain injury annually. This is of considerable concern as concussive injuries may have detrimental effects on the youth's development and scholastic performance (McCrory & Davis, 2005).

Attitudes and behaviours legitimizing aggression and violence in ice hockey are well documented, in both the scientific literature (Sheldon & Aimar, 2001; Smith, 1988; Weinstein, Smith, & Wiesenthal, 1995) as well as the popular press (Dryden, 2004). Youth learn that

injurious actions, such as cross-checking, high-sticking, and boarding, may be justifiable strategies if they increase a team's chances of winning. These attitudes and actions are primarily internalized through observational learning of and perceived approval by significant others, such as professional players, coaches, team-mates or parents (Bryant & Zimmerman, 2003; Pleiss & Feldhusen, 1995).

In an effort to reduce the injurious behaviours and attitudes of youth hockey players that can lead to concussion, an educational hockey video game, *Alert Hockey*[1] (formerly *Heads Up Hockey*), was developed. The game was designed to modify game playing behaviour by embedding a subtle teaching mechanism within the gameplay. By embedding this teaching mechanism *implicitly* rather than *explicitly*, the goals of the game, at least to the participant, remained the same as in all games—to win. That is, participants tried to outscore the computer-controlled opponent by skillfully playing the video game; there was no intent on behalf of the player to learn about concussions. An additional benefit of this approach is that the implicit nature of the instruction does not impede a player's enjoyment of the game, which is a common problem amongst existing educational titles (de Castell & Jenson, 2003). The expectation was that if we could maximize player engagement with the game we would create a captive audience and, in turn, a potentially receptive learner.

The problem of "Indirection"

Educational games often suffer from the problem of "indirection", that is, the content the learner is intended to learn is only indirectly related to the gameplay. Indirection within an educational game is the result of a design that disassociates the gameplay from the content, which Rieber (1996) calls an "exogenous fantasy". For example, a fictional educational game might reward a successful match of *Tic-Tac-Toe* with a lesson on Canadian History. Playing *Tic-Tac-Toe* is meant to extrinsically motivate learners to absorb the Canadian History content. However, the relationship between Canadian History and *Tic-Tac-Toe* is bound by a behaviourist mechanism that artificially relates the game to the content. There are several real world examples of indirect educational games, including *Math Blaster* and *The Typing of the Dead*. These games and many others suffer from the problem of indirection, with the result failing to maximize the objectives of fun or learning

Although not numerous, there are several studies that support the premise that indirect educational games are no more effective than regular teaching materials. McMullen (1987) investigated the effect of informational, drill, and game format computer-assisted instruction (CAI) on the achievement, retention, and attitude toward instruction of sixth-grade science students. An informational CAI lesson on Halley's Comet was administered to three randomly selected groups of sixth-grade students. A CAI drill about the content of the informational lesson was given to one group, and a CAI game was given to another group; only the informational lesson was presented to the third group. No significant differences were found between the groups on a post-test measuring achievement given immediately after the instruction or on a retention post-test given one month later.

Din and Caleo (2000) investigated whether kindergarten students who played the *Lightspan* console learning games learned more than peers who did not play such games. The Lightspan learning games suffer from indirection in that the goals of the game (e.g. to teach

math) are not directly related to the gameplay. The experimental group played the games for 40 minutes per day in school for 11 weeks. Findings from the data analysis indicated that the experimental group performed no differently than the control group in the math area. Although this study did produce some positive results in areas that have historically responded well to drill and practice models (e.g. spelling), the authors concede further research must be performed to say that playing the *Lightspan* series leads to learning.

Implicit learning

One possible response to the problem of indirection is to build games using an *implicit* learning approach. Implicit learning is "the process by which knowledge about the rule-governed complexities of the stimulus environment is acquired independently of conscious attempts to do so" (Rieber, 1989). One of the criticisms of educational video games is that they are often neither fun, nor educational (de Castell & Jenson, 2003). This results in the game player losing attention, thereby reducing the likelihood of understanding, recall or appropriation. Attention plays a critical role in issues of motivation, engagement, and learning across educational settings (Rapp, 2006). Designing educational games to utilize our ability to implicitly learn holds promise for easing the conflict between enjoyable gameplay and educational content, thereby producing a more captivating learning experience. Our goal in this project is to extend the use of principles related to implicit learning to maximize the game's playability, and, in turn, participant attention and learning

Our understanding of implicit learning is largely based on a blend of cognitive, neuroscientific and computational approaches (Jimenez, 2003). Cognitive science has explored the roles that memory, attention, awareness and reason play in our ability to learn implicitly (Frensch, 1998; Shanks, Rowland, & Ranger, 2005; Tomlin & Villa, 1994). These studies indicate that memory, attention, awareness and reason not only are key contributors to explicit learning, but also to how we learn implicitly. Neuroscience has attempted to identify the neural structures, such as the prefrontal cortex and medial-temporal lobe, that contribute to our ability to learn implicitly (Hazeltine & Ivry, 2003; Rose, Haider, & Buchel, 2005). Computational analysis has emphasized the functional implications of current implicit learning models by treating the brain as a black box and focusing on input and output more than process (Destrebecqz & Cleeremans, 2003). In recent years, the study of implicit learning has become increasingly integrated with the conceptual and philosophical debates concerning the nature and functions of consciousness (Jimenez, 2003). That is to say that implicit learning is now seen to be a central concept in our understanding of consciousness and of learning in general.

The Design of *Alert Hockey* and Karma

The goal of the game design was to create an implicit teaching mechanism that would penalize aggressive behaviour, and reward non-injurious behaviour. In addition, the occurrence of a reward or penalty would not be directly revealed to the participant, thus allowing the learner to discover the connection between positive behaviour and reward on their own terms. This feature is widely recognized by constructivists as important in all complex real-world learning situations (Jonassen, 1997), which in this case is exaggerated for effect. Thus, the notion of 'karma' was established, that is a system to keep track of aggressive and negligent player events and subsequently alter the player's ability to win. Similarly, if a player exhibits positive

behaviours, the karma system would reward the player with a greater ability to win. We believed karma would be an effective paradigm to change behaviours because, regardless of the very real limitations of the behaviourist tradition in understanding the mechanisms of mind and therefore its limitations as a predictive paradigm, there is little doubt that behaviour is generally influenced by the effects of prior experience. If we perform certain actions and those result in unfavourable outcomes, we will consider changing our behaviour (Burton, Moore, & Magliaro, 2004). This extends to the situations where actions and outcomes do not seem to be directly connected (Vyse, 1997). Superstition is one such manifestation of our natural tendency to change our routines based purely on coincidental correlation between events, also known as the post hoc fallacy. For example, some hockey goaltenders touch their posts before each game because they believe that act will bring them good luck. By creating a karmic mechanism that is based on situated and constructivist learning principles, and takes advantage of our innate ability to correlate actions with outcomes, we hoped to change perspectives, habits and ultimately, gaming behaviour.

A participant's *karma* level[2] is determined by their game play behaviour. That is, aggressive behaviour, defined as a set of in-game transgressions such as charging or hitting the goaltender, lead to a decrease in karma. In addition, actions (or lack of actions) we defined as 'negligent' behaviour also led to a decrease in karma level. For example, a participant's failure to deal with the concussed player by permanently removing them from the game lineup was considered an act of negligent behaviour. Aggressive and negligent karma penalties differ in that the former are one time subtractions (per transgression), whereas negligent karma penalties continually accrue until the negligent behaviour ceases.

The goal of the karma mechanism was to change a player's gaming behaviour to be less aggressive and negligent through a reward/penalty system. Moreover, a player gained positive karma by refraining from those actions considered to be aggressive and negligent behaviours (see Table 1). Thus, the only way to accrue positive karma was to play responsibly and wait for the positive accumulations to have effect.

Table 1: *The aggressive and negligent behaviours that incur karma penalties*

Aggressive	Negligent
Interference	1 injured player in lineup
Run the Goalie	1 injured player on ice
Multiple Hits	> 1 injured player in lineup
Charging	> 1 injured player on ice

Once we had established our model for increasing and decreasing karma based on a player's behaviour, we then had to map the range of karma values to an effect on gameplay. It is important that this mapping correlates karma with the participant's goal differential. That is, karma must be a significant factor in deciding whether a player wins or loses. The basis of our

teaching mechanism relies on the player associating positive behaviour with winning. Therefore, each limit of the karma scale, from -100 to +100 needs to seriously impede or aid the player. To accomplish this, we engineered karma to have an effect on all of the player's abilities, from shooting to skating. For example, if a player was able to behave positively and acquire a high karma score, their team would start skating faster, shooting harder and so on. In this way, we ensured that karma scores were positively correlated to winning.

Study Design

A study was designed to determine whether the karma mechanism significantly altered gameplay behaviours. More specifically, the primary aim of this study was to determine whether participating in *Alert Hockey* elicited a positive change in mean karma (behaviour) within the experimental group. In order to establish this, we must first determine whether the karma mechanism was operating as intended. We do this by predicting that goal differential will be positively correlated to the behaviour score for the experimental learning group. In addition, there should be no correlation between goal differential and behaviour score within the control group. This says that as the experimental learning group improved their behaviour, the more successful they were at the game. With respect to the control group, no correlation means that their aggressive or negligent behaviour had no system-influenced effect on their success. Finally, we predict that, through the implicit learning process, the experimental learning group will improve their mean karma scores (behaviour) over time as compared to the control group.

Participants

Experience with testing a prototype version of *Alert Hockey* revealed that the game remained engaging over a period of time only for certain age groups (Ciavarro, Meanley, Bizzocchi, & Goodman, 2005). From debriefing, it was clear that those participants who were 15 years of age or over were not enthusiastic about playing the game for extended periods, perhaps because the game was not powered by the latest 3D graphics employed by today's popular digital games. This observation led us to restrict our study's participant age range to 10 to 14 years of age in an attempt to engage those with an interest in the game. Informed consent was obtained for a total of 74 participants from local lacrosse teams and summer camps. The mean age of participants was 12.2 years, with a standard deviation of 1.3 years.

Experimental groups

There were two experimental groups and one control group. One experimental group, Karma Effective Positive (*kep*; n = 28) participated in a game environment which rewarded less aggressive and negligent behaviour with enhanced player attributes, and thus a greater likelihood of scoring and winning. A second experimental group, Karma Effective Negative (*ken*; n = 22) participated in a game environment in which aggressive and negligent behaviour was rewarded with enhanced player attributes and a greater likelihood of winning. This condition was opposite to that of the *kep* group. The control group, Karma 0 Positive (*k0p*; n = 24) did not experience karma effects. Participants were randomly assigned to groups and were not informed about their group identity.

Test Session

Each player participated in three separate sessions of five games per session for a total of 15 games each. Each session lasted approximately one hour. The only instructions from the study administrators were "to have fun". At least one day between sessions was required to enhance the likelihood of meaningful reflection and to reduce the chance of "burnout" playing *Alert Hockey*. At the start of the first session, participants were presented with a screen prompting them for their first name, last name and age. After providing this information, the player moved to the game's title screen. Before each of the 15 games, the participant was presented with 8 instructional screens about how to play *Alert Hockey*, such as how to pass and shoot. There was no mention of karma or the intent of the instructional design.

Data Collection

During gameplay, several streams of information were collected including regular hockey statistics such as shots, goals and attack zone time. In addition, a play-by-play file was recorded which contains every incident of aggressive behaviour alongside regular hockey plays (e.g. a shot or a goal). The distinguishing characteristic, the effect of karma, was an 'internal game variable' designed to influence game behaviour. The karma attribute was recorded for each group, to allow for comparisons between groups. The mean karma levels were recorded on a per period basis by sampling karma once every second and adding it to the accumulator *kacc* (1). To get a per-period mean karma score (*ppavgk[per]*), the value of the accumulator was subtracted by the sum of the previous period's accumulator values, and divided by the number of seconds in a period (2). The mean karma score for a game (*gavgk*), which we use as our base unit of analysis, was the average of the three per period karma means, or the final accumulator value divided by the number of seconds in a game (3). All karma measures were initialized to zero at the start of every game.

(1) $\quad kacc = kacc + karma$, once per second

(2) $\quad ppavgk[per] = \dfrac{kacc}{mpp * 60 + spp} - \sum_{i=1}^{per-1} ppavgk[i]$

(3) $\quad gavgk = \dfrac{\sum_{i=1}^{3} ppavgk[i]}{3}$ $gavgk = \dfrac{kacc}{3(mpp * 60 + spp)}$
 or

Analysis and results

The data was first examined for quality. Through observation, we discovered some participants were disinterested or tampered with the game. To gauge disinterest, we asked each participant if they tried their best to win at *Alert Hockey*. If a person reported that they did not try their best and were also on a list of participants observed to be exhibiting disinterest, they were excluded from the analysis. With respect to tampering, there was a loophole in the game that allowed the participant to inadvertently reset the game settings, which resulted in the

removal of another three participants from analysis. This data was excluded from analysis due to the repeated measures design. Overall, 62 out of 74 participants were included in the subsequent analyses. This resulted in 21, 20, and 21 participants in the *kep*, *ken* and control groups, respectively.

Correlational analysis

There were clear expectations with respect to the relationship between the experimental conditions and game outcome (assessed by goal differential between the player and the computer). That is, in the *kep* condition, game play with low levels of aggression and negligence (and hence higher karma levels) leads to better performance of the team players (e.g. harder shots, faster skating). This in turn was expected to lead to a positive goal differential. The significant correlation (r = 0.73, p < .05) was consistent with this prediction. On the other hand, in the *ken* condition, where aggressive and negligent behaviour was rewarded (while the karma variable decreased), karma was expected to be negatively related to goal differential. This predicted relationship was again evident (r = -0.68, p < .05). The results from the control condition, *k0p*, were also consistent with predictions in that the relationship between karma and goal differential was non-significant (r = 0.06). Figures 1, 2 and 3 show the scatter plots of mean karma scores and goal differential (home [player] score minus away [computer] score) for each game within a single condition.
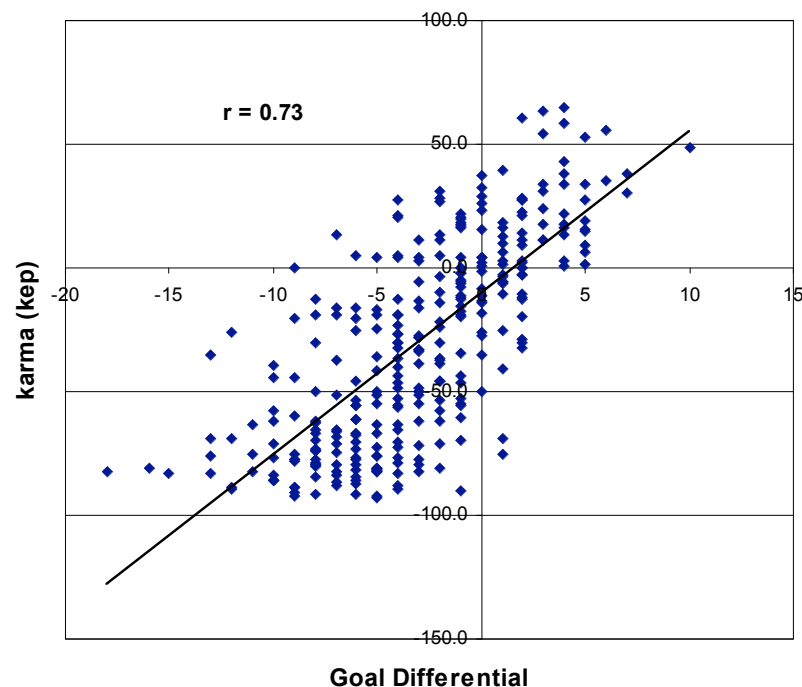

Figure 1: Scatter plots of karma and goal differential for *kep* participants, with Pearson's r
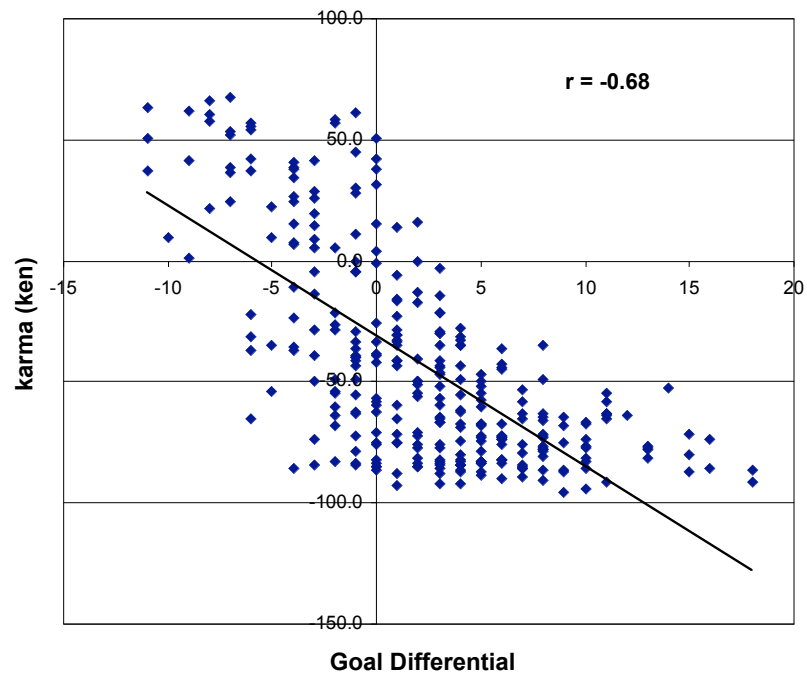
Figure 2: Scatter plots of karma and goal differential for *ken* participants, with Pearson's r
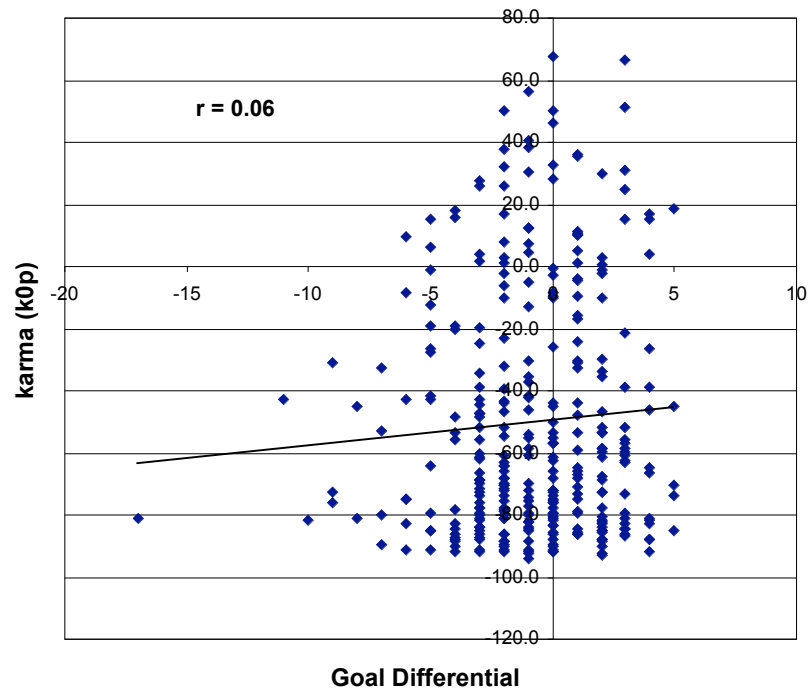

Figure 3: Scatter plots of karma and goal differential for *k0p* participants, with Pearson's r

Behavioural analysis

In order to examine changes in behaviour across the experimental groups, a two-factor repeated measures ANOVA was carried out. We expected the control group (*k0p*) to exhibit essentially no change in karma scores (behaviour), whereas the experimental group *kep* should learn from the karma mechanism and improve their behaviour. In contrast, we anticipated only a minor negative change for the *ken* group given that most hockey players tend to play (both on the ice and in our sports action video game) aggressively, thereby leaving little room for significant drops in karma scores. The five karma scores in each of three sessions were averaged to give a single session score. As expected, the *kep* group increased their karma scores over playing time. No change was apparent in the control and *ken* conditions.
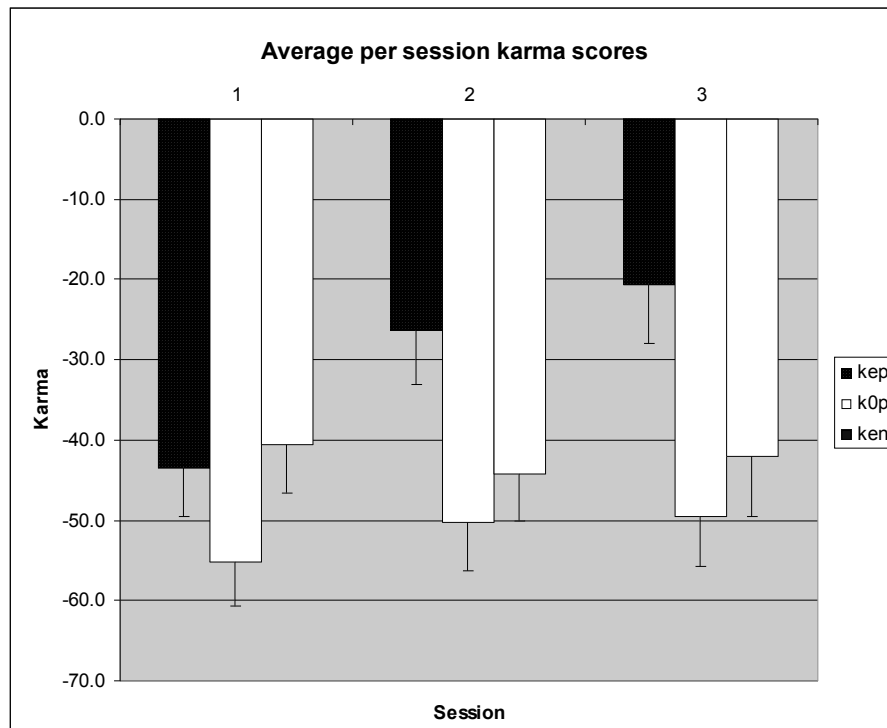

Figure 4: Mean karma per session plot

The ANOVA revealed the main effect of session to be significant ($F_{(2, 122)} = 3.984$, $p = 0.021$), indicating that time exposure had an effect on karma. As expected, the important interaction between condition and session was significant ($F_{(2, 122)} = 2.862$, $p = 0.026$). The expectation was for the *kep* condition to increase their karma scores more so than the control group. As illustrated in Figure 4, the *kep* group appears to have considerable influence in improving overall karma scores.

Table 2: *Means and standard deviations for overall karma data*

Condition		Mean	Std. Deviation	N
Session1	*K0p*	-55.20	26.24	21
	ken	-40.52	27.01	20
	kep	-43.52	27.20	21
	Total	-46.51	27.14	62
Session2	*K0p*	-50.28	28.46	21
	ken	-44.21	26.60	20
	kep	-26.30	31.31	21
	Total	-40.20	30.23	62
Session3	*K0p*	-49.50	28.83	21
	ken	-42.09	33.59	20
	kep	-20.73	33.26	21
	Total	-37.37	33.76	62

Given the significant condition by session interaction, we ran three separate 1-way ANOVAs with repeated measures on each condition in order to determine which groups significantly changed their karma scores over time. The *kep* condition was the only group that had a significant main effect ($F(2, 40) = 10.589$, $p = 0.0002$). Follow-up post hoc analysis revealed a significant linear trend ($p = 0.0004$). Neither the *k0p* or *ken* groups changed significantly with respect to their karma scores over the three sessions.

Conclusion

This paper describes the assessment of the educational sports-action video game *Alert Hockey*. The context of this game is concussive injury in hockey, with the intent to reduce the behaviours that can lead to concussions. The question asked here was how educational digital games can be developed in a way that preserves inherently enjoyable gameplay aspects at the same time as reliably changing learner outcomes. After identifying a common problem of past educational gaming efforts (indirection), the answer reached in this paper was to use an implicit teaching mechanism that situates the learner in a role where they can learn through authentic

challenges. In order to test this concept and advance the methods of concussion education, we designed and built *Alert Hockey*, with an implicit teaching mechanism that we labelled 'karma'.

The results of the assessment study clearly showed that the implicit teaching mechanism performed as intended. The composite behaviour score karma significantly improved over time amongst the experimental participants as compared to the control group. Reduction in negligent behaviour was the primary reason for the overall improvement in karma with the experimental group. The individual negative components of the composite karma score (aggressive and negligent) did not significantly decrease, as they were designed to work in concert with each other and positive karma to affect behaviour. This is why the primary evaluation of the effectiveness of the karmic teaching mechanism is based on the composite karma score.

The encouraging results we have thus far can be primarily attributed to the design of the implicit learning mechanism. The notion that participants would be able to associate a particular game playing behaviour with success or failure was based on the post hoc fallacy. That is, the participants would assume their actions were causing certain outcomes even if there was no apparent correlation (Vyse, 1997). This was the heart of our implicit teaching mechanism, and thus the primary driver behind our results. However, there were other factors that contributed to the success of *Alert Hockey*. In particular, we were able to expose each player to the implicit teaching mechanism for a significant amount of time because the participants remained engaged with the game. Several participants inquired about when they might be able to purchase the game or if they could continue playing it while they waited for a ride. Without this kind of enthusiasm for playing, the learning that did occur may have been impeded. Keeping in mind our ultimate goal of increasing the safe play behaviour of youth hockey players, we believe it is essential to design an engaging environment as well as an effective teaching mechanism.

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[1] The game was created as part of a multi-year CIHR grant addressing concussion injuries in youth hockey. Canadian Institutes of Health Research, Grant # CAR-42276, D. Goodman, P.I.

[2] *karma* is represented within the game engine as a variable integer between -100 and +100.