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The influence of peer accountability on attention during gameplay

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ABSTRACT

The comparative advantages of competitive and cooperative multiplayer gameplay designs have been studied with mixed results. In this study, we have attempted to minimize other cooperative design attributes in order to focus on evaluating the effects of strong peer accountability on players' overall and sustained attention levels during competition and cooperation. A novel multiplayer game based on a cognitive task that uses the Stroop effect was developed and deployed in trials where quantitative in-game data measuring players' error rates and reaction times were collected for comparative analysis. The results show that players demonstrate higher levels of attention when they were made accountable to their partners as they make significantly less errors when cooperating than when competing. In addition, the individual response time data gathered reveals that peer accountability has a more positive influence on the performance of the slower partner and this performance improvement was not sustainable under situation where large performance disparity existed within the team. Physical proximity however, was not observed to have any significant positive influence on players' performance during cooperative gameplay.

1. Introduction

Competitive and cooperative game mechanics are basic elements used by multiplayer game designers to increase motivation and engagement. Several researchers have studied their comparative effectiveness and influence on players' performance. For instance, competition and cooperation have been studied from the viewpoint of goal structures and the cooperative goal structure was found to result in higher motivation and effort in a motor-centered activity (Peng & Hsieh, 2012). Others examined how scoring mechanisms based on principles of collaboration and competition impact the accuracy and engagement of players in commonsense knowledge collection tasks (Siu, Zook, & Riedl, 2014). Their results show that the competition-based scoring mechanism maintained the accuracy and increased engagement. Besides goal structures and scoring mechanisms, cooperative game design patterns can take a variety of other forms in game mechanics, such as shared goals, synergies between abilities, complementary roles and so on (Seif El-Nasr et al., 2010). Comparative studies have so far yielded mixed results due to the use of different cooperative design attributes and it remains unclear what influence the various cooperative design features or confluence of features may have on motivation and engagement. In addition, performance in a cooperative setting can be often complicated by variations in the group composition such as the ability disparity between members in the team (Yuan, Tu, Li, & Ning, 2016) and space features such as the physical proximity between partners (Hawkey, Kellar, Reilly, Whalen, & Inkpen, 2005; Nova, 2005).

In this study, we are particularly interested to examine the influence of peer accountability on players' behavior. Studies in organizational behavior research have shown that accountability, either as a threat or an opportunity, has a wide range of influence on cognitive activities such as emotional labor, focus, opinions, perceptions, and attentiveness (Hall, Frink, & Buckley, 2017; Lerner & Tetlock, 1999). In a purely competitive multiplayer gameplay, the players are only accountable to themselves. In cooperative gameplay, on the other hand, the players are not only accountable to themselves but also accountable to their team mates. The model of social judgment and choice (Tetlock, 1985) argues that accountability can serve as a fundamental force to drive a person's behavior and decisions because individuals are concerned about their self-image and status in the eyes of others. The impact of accountability has been extensively addressed in psychology and organizational behavior research but studies examining the role of

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accountability on multiplayer behavior in game design are still wanting, especially in context of comparison between competitive and cooperative gameplay, and is therefore the focus of this study.

In order to design this comparative study on a cooperative gameplay which emphasizes peer accountability and contrast its influence relative to a competitive equivalent, care must be taken to minimize the influence of other cooperative design attributes. Firstly, the task in which the players' performance is measured during gameplay must remain essentially the same in both the cooperative and competitive modes. In this way, the measurements obtained in the two gameplay modes can be compared directly and without bias. Secondly, while maintaining the constraint mentioned earlier, the notion of peer accountability must be embedded in the game mechanics and made explicit to the cooperating players. To achieve these goals in our cooperative game design, the progress of one player is made dependent on the other in a conjunctive manner but not their individual performance measure.

In particular, we designed a competitive and cooperative version of a game that employed a simple cognitive task, namely the Stroop task (MacLeod, 1991). This task has been widely used in neuropsychological studies as a measure for selective attention as the task can be error-prone and requires sustained attention for fast and accurate performance. In addition, the straightforward Stroop task game was intentionally kept basic and uninteresting. As pointed out in (O'Keefe, Horberg, & Plante, 2017), a task that is inherently interesting requires little effort in soliciting the player's attention. In contrast, an uninteresting task requires the player's conscious effort to motivate attention in order to stay in the game. Using such stimuli, the measured attention levels of the players are likely to be dominated by the social influences of the competitive and cooperative attributes rather than the game itself.

Attention is an important component of engagement and immersion (Jennett et al., 2008). Attention is also strongly related to learning outcomes in the educational context (De Castell & Jenson, 2004). Thus measuring the players' performance in terms of their attention level may shed some light on a wider question of whether a competitive or cooperative scenario will be more effective in stimulating and sustaining players' engagement during gameplay. However, the scope of attention can be either broad or narrow and each leads to a different mode of engagement (O'Keefe et al., 2017). During an exploratory activity such as doing flower arrangement, one's attention is broad in scope and engagement is mostly driven by curiosity. In contrast, the delicate task of hammering a small nail will narrow and focus the scope of one's attention to the exclusion of other irrelevant competing stimuli. The scope of attention addressed with the Stroop task design is narrow and as such, our results can be generalizable to activities with well-defined performance measures such as response time, accuracy, correctness and high scores.

Additionally, the Stroop task design allows us to make quantitative measures of the players' cognitive state in terms of the players' speed and accuracy in answering each question. Such measures are more objective and do not depend on players' subjective perception and experiential recall when they are asked to rate the attention levels of different gameplay modes in post-trial questionnaires. Unlike subjective measures, individualized quantitative measures acquired during gameplay also allow us to analyze several interesting gameplay behaviors of the players. Firstly, the temporal variations in each player's response time allow us to study not only the overall attention level of the players but their ability to sustain this attention during the gameplay duration. Secondly, the individualized performance measures during gameplay permits us to investigate the differences in behavior between the stronger and weaker performers in a cooperative setting and the influence such disparities has on the players' attention levels.

In summary, this study has several related objectives. Firstly, we are interested to compare players' engagement in terms of overall attention level and sustained attention when playing a cognitive-oriented game in a competitive play mode and in a cooperative play mode with strong peer accountability. Secondly, given that the performance disparity between cooperating partners is known to have an impact on player's behavior, this study investigates the difference in engagement levels between the stronger and weaker performers and what influence the extent of this performance disparity has on the ability of the players to sustain their attention throughout the gameplay. Finally, given that such cooperation can be performed either remotely (apart) or in a co-located (close proximity) manner, this study also set out to investigated if physical proximity has any significant influence on players' attention level during cooperative play.

2. Literature review

2.1. Accountability

In social psychological literature, individual level accountability is defined as "an implicit or explicit expectation that one's decisions or actions will be subject to evaluation by some salient audience(s) with the belief that there exists the potential for one to receive either rewards or sanctions based on this expected evaluation." (Hall & Ferris, 2011). Accountability to others has been regarded as an important social psychological link between individuals and social systems (Tetlock, Skitka, & Boettger, 1989). It should be noted that the peer accountability discussed in this study refers to felt accountability, which is focused on the actor's subjective interpretation of accountability from a phenomenological view of accountability (Frink & Klimoski, 1998) as opposed to the attribution of accountability from audiences' point of view (Folger & Cropanzano, 2001).

Empirical research has shown that accountability can influence people in many ways, including cognition, behavior, affective states and decision making (Hall et al., 2017). For instance, the studies on social interdependence theory suggested that it is crucial for educators to make sure that the individuals' outcomes are affected by each other's actions and each student is held accountable in order to promote effective cooperative learning (Johnson & Johnson, 2009). However, the consequences of accountability are not always beneficial. High level of accountability was also found to be associated with some negative outcomes, such as higher depressed mood at work, lower levels of organizational commitment and work intensity, and decreased job satisfaction, especially when there is a low level of fit between person and organizational environment (Lanivich, Brees, Hochwarter, & Ferris, 2010).

When it comes to cognitive activities in particular, studies in organizational behavior research have found that accountability can affect what people think (e.g. preferences) and how people think (e.g. reasoning) (Lerner & Tetlock, 1999). Yet there is little research in multiplayer gameplay investigating how the accountability to cooperating peers might influence a player's cognitive state. In cooperative gameplay, the existence of team mates as salient audiences can exert extra responsibility and accountability and might alter players' cognitions and behaviors when the actors explicitly or implicitly regard these "account" as part of their self-images to protect and enhance, as pointed out by the model of social judgment and choice (Tetlock, 1985). Therefore, one of the goals in this study is to investigate the influence of peer accountability on players' attention in a multiplayer gaming environment.

Furthermore, the complex relationship between accountability and cognition can be moderated by many other factors such as the characteristics of the audience. For example, while being required to give opinions on a controversial issue, subjects tended to shift their views towards the position that they thought the audiences held (Tetlock et al., 1989). And other studies found that the cognitive effort participants spent on the discussion under accountability pressure were related to their partner' relative expertise (Fitzpatrick & Eagly, 1981). Specifically, when the subjects thought their partners processed similar level of expertise on the topic as themselves, they were observed to give more cognitive effort. Based on this interesting observation, another goal of this study is to investigate if a player's cognitive state during cooperative gameplay will be affected by their partner's relative performance level.

2.2. Selective attention

Research on competition and cooperation has been conducted with various gameplay genres, like motor-centered, mathematical and brainstorming games, and they involved different application domains, such as serious games, educational games, games with a purpose (GWAPs), etc (Peng & Hsieh, 2012; Plass et al., 2013; Siu et al., 2014; Tausch, Ta, & Hussmann, 2016). This study is focused on a simple cognitive game with no particular application domain, where sustained selective attention is required for good performance. Selective attention refers to the ability of attending selectively to certain aspects in a situation, while simultaneously ignoring irrelevant information that is also present. We use this in our daily interactions as it is impossible to give attention to every stimulus in the environment.

In 1935, J. R. Stroop (Stroop, 1935) published his landmark work on attention and interference in which the Stroop effect was proposed and it has since been widely used as a measure for selective attention in numerous psychological studies. In the Stroop Color-Word Interference Test, the subjects will see a series of words and are required to name the color each word is printed in instead of what the word spells. Research findings observe that when the color of the ink does not match the name of the color (incongruent condition), the subjects take a longer time and are more prone to errors in naming the color than in the congruent condition. The Stroop test involves two stimuli, one is the target (color), and the other is the distractor (word). While facing two stimuli, attention is needed to decide whether to attend to the ink color or the word analyzer when each leads to a different potential response. Generally, performance on the Stroop task is taken as the “gold standard” for selective attention (MacLeod, 1992) and has been widely used in neuropsychological study as a measure for selective attention in studying individual differences, drug effects and so on. For example, to investigate functional anatomy of attention, measurements to the changes in regional cerebral blood flow were taken while subjects were performing the Stroop test (Bench et al., 1993).

2.3. Multiplayer gameplay: competition versus cooperation

Numerous studies have investigated the relative influence of competitive and cooperative designs on players' behavior. In physically-oriented exergames, competitive play has been found to increase energy expenditure and aggression, while cooperative play has been found to increase motivation, pro-social behaviors and promote continued play (Marker & Staiano, 2015). A study related to stress reduction indicated stress levels declined over time at equal levels during both competitive and cooperative game play but participants in the competitive condition were observed to have a slightly less positive impression of the opponent following the gameplay (Roy & Ferguson, 2016). Some positive social benefits of playful competitive gaming were reported for children in a longitudinal study. Decrease in conduct problems and improvement in peer relations were observed (Lobel, Engels, Stone, & Granic, 2017). Besides these psychological and social effects of cooperative and competitive gameplay, some studies also examined their physiological influence. While playing an action game (Bomberman), subjects exhibited higher levels of physiological activities (facial EMG, respiration, electrodermal and cardiac activities) in competitive play than cooperative play (Chanel, Kivikangas, & Ravaja, 2012). When it comes to motor performance, an extensive meta-analysis of the relative impact of cooperative, competitive and individualistic efforts on motor skills tasks suggests that cooperation is the mode that promotes higher performance on motor skills tasks under most conditions (Stanne, Johnson, & Johnson, 1999). Another more recent study on a motor activity-centered computer game partially supports this argument in the sense that they observed cooperative goal structure can lead to greater motivation to put efforts in the game compared to the competitive version, yet no significant differences in performance were observed (Peng & Hsieh, 2012). In addition, some studies examined some factors that may moderate the impact of competitive and cooperative gameplay, such as performance feedback, players' pre-existing relationship, team ability disparity etc. A study on the influence of performance feedback during casual online gameplay found that players had a more favorable perception of their partners when winning cooperatively and their competitors when losing competitively. However, they rated their cooperating partners less favorably when they lost together and their competitors when they beat them. (McGloin, Hull, & Christensen, 2016). As for pre-existing relationships, cooperating with friends was found to result in a stronger goals commitment than partnering with strangers (Peng & Hsieh, 2012). However, relationships did not have any significant influence on the participants' feelings of hostility or cooperative behaviors after competitive and cooperative gameplay in a violent video game (Waddell & Peng, 2014). As for team ability disparity (Yuan et al., 2016), the performance in a competitive reward structure was higher than in a cooperative structure for teams with large disparity. However, when the disparity is small, no significant difference was observed. Furthermore, studies also reported the socio-cognitive functions of space features for co-located collaboration settings (Nova, 2005). For instance, majority of participants felt that sitting close together with partners was more effective and more enjoyable for collaboration since communication was easier (Hawkey et al., 2005). Besides the convenience for initiating and conducting conversation, close proximity can also help maintain task and group awareness (Nova, 2005).

In the area of education, it has long been established that interaction with peers is an effective way of developing skills (Vygotsky, 1978) and that knowledge construction is a social and collaborative process (Light & Littleton, 1999; Scardamalia & Bereiter, 1991). Works on cooperative learning in the classroom context suggest peer collaboration can have a positive influence on learning outcomes as well as on general attitude of learners (Creighton & Szymkowiak, 2014; Slavin, Leavey, & Madden, 1984). For example, a study employing cooperative and competitive versions of the Wii games in a classroom setting found that cooperative games can benefit the social interaction of students with behavior and learning difficulties by increasing their classroom interaction frequency (Creighton & Szymkowiak, 2014). However, it should be noted that such positive effect of cooperative learning does not always occur by simply placing students in groups. In fact, from the motivational perspective, in order to make cooperative learning effective and successful, some key components like shared goals and individual accountability are quite essential (Slavin, 2014). Other factors, such as group composition (Lou et al., 1996), and instructional material in terms of the type of knowledge involved (Mullins, Rummel, & Spada, 2011), may also affect the effectiveness of cooperation learning. Besides collaboration, the advantages of competition have also been reported in some research studies. In an educational mathematics game-based study, although both competitive and cooperative modes stimulated greater situational interest and enjoyment compared to individual play, only the competitive play mode was found to increase game performance. The collaborative play mode on the other hand, had a higher reengagement potential (Plass et al., 2013).

Other researchers have studied how cooperative and competitive elements can be employed to improve productivity. Such applications include labeling data, collecting commonsense knowledge etc. For example, one study examined how the outcomes of crowdsourcing are affected by social transparency and different peer-dependent reward schemes (Huang & Fu, 2013). The results have shown that social transparency applied to a collaborative scheme that rewarded the collective output of the paired workers helped reduce social loafing through peer accountability. On the other hand, social transparency applied to a scheme that rewarded workers based on how much they can outperform the other actually increased the incentive to compete, thus increasing their output relative to those who work individually. These results suggest that an appropriate peer-dependent reward scheme design can motivate higher output from workers. Another study investigated the influence of competitive and cooperative visualizations on performance, pressure, balance of participation for group mirrors in a brainstorming session (Tausch et al., 2016). Their findings suggest that visualizations having a mixture of competitive and cooperative features stimulated the highest productivity and satisfaction in terms of the number of ideas generated during the brainstorming session.

As can be gleaned from the findings of the many previous works, the comparative advantages of competition and cooperation seem varied, inconsistent and dependent upon various factors such as team composition, task type and dimension, etc (Beersma et al., 2003). A majority of the past research reviewed presented analysis from data derived from subjective questionnaires. In contrast, our study has employed quantitative measures to analyze the differences in players' attention during competitive and cooperative gameplay. As such, this permits us to carry out experimental analysis related to the disparity in performance abilities between each pair and players' temporal degradation in performance during gameplay.

2.4. Terminology and notation

Several notations adopted in this paper need clarification. In traditional game theory, games are divided into two basic types: competitive and cooperative. However, in the game design community, a third type, collaborative games has been differentiated as "*Cooperative players may have different goals and payoffs whereas collaborative players have only one goal and share the rewards or penalties of their decisions.*" (Zagal, Rick, & Hsi, 2006). Based on their definition, the cooperative design in this study is actually collaborative in nature because the two partners have one collective goal and share the rewards or penalties. However, to maintain consistency in notation with most related works in the literature, we have adopted the word *cooperation* in this paper.

Besides competition and cooperation, some works combine the two to examine the effectiveness of inter-group competition. Investigations on the influence of pure competition, pure cooperation and inter-group competition on motor performance in a basketball free throw activity found that inter-group competition led to higher levels of intrinsic motivation and performance (Tauer & Harackiewicz, 2004). In the pure cooperation condition, the team's goal is to exceed a target number (computed as the mean of previous individual scores) while in the inter-group competition condition, the team's goal is to exceed another team's score. Based on this definition, it should be noted that the cooperative mode in our study is effectively inter-group competition. In short, the goal of our competitive gameplay mode is for each individual to beat the other player and the goal of our cooperative gameplay mode is for the pair to work together to beat the scores of the previous team.

3. Method

3.1. Participants

Participants (N = 40) comprising of undergraduates and graduates were recruited from a large university. Their ages ranged from 20 to 41 years (M = 26.41, SD = 5.34). 55% of participants were male and the rest female.

3.2. Stimuli

Based on the Stroop effect, a tablet computer-based game was designed focusing on the incongruent condition with unmatched color and word pairs. During the game, the players see a set of words. The colors of the words do not match the words' meaning, such as shown in Fig. 1(a), the word "Blue" is in red-colored fonts. Players are required to select the matching color of the words. For example in Fig. 1(a), the correct answer is "Red". The goal of the game is to complete as many questions correctly as possible within the 90 s allocated per round. This multiplayer game is designed with two gameplay modes, namely cooperative and competitive modes. To ensure the two players start the game simultaneously, a third tablet computer (acting as a server) was used by the facilitator to initiate the game when both the players were ready to start.

In competitive gameplay, the goal of each player is to surpass the score achieved by the other. As seen in Fig. 1(a), the current number of correct answers is shown on the top of the screen and the elapsed gameplay time in shown on the bottom left. The two players play independently. After 90 s is over, the one who completed the most questions correctly will be announced as the winner with a "Win!" flashed on her tablet, while the other player receives a "Lose". Both receive a "Win!" in the event of a tie.

In cooperative play, the goal of the game is to beat the score the previous participating team achieved during their corresponding round. The team will be informed whether they have won or lost at the end of each round. Team members cooperate in the following manner. Both will receive the same question simultaneously. As seen in Fig. 1(b), there are two locks on display. Each player controls one lock. More specifically, if one finishes the question correctly, he will see the left lock open with the sound of a delightful chime and if his partner also finishes the question correctly, he will see the right lock open as well. However, if one team member answers the question incorrectly, a red cross will appear on the corresponding lock, as seen in Fig. 1(b), along with the sound of an error buzzer. Only when both players make their selection, can they move on to the next question. If any of the two answers is incorrect, the team gets no points.

Note that in the design of this cooperative game mechanics, the cognitive task for each individual player remains identical to that in the competitive mode, which is essentially the Stroop test task. As such, we can make a fair comparison of the performance data collected in all the gameplay modes. However, peer accountability

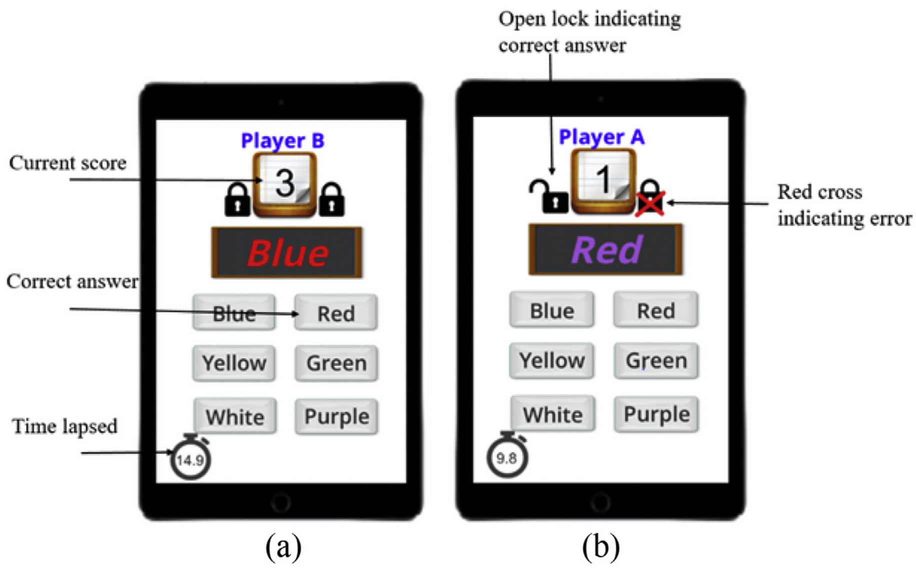

Fig. 1. Multiplayer game based on the Stroop effect: (a) The game screen of player B in the competitive mode. The locks are inactive. (b) The game screen of player A in the cooperative play, where player A has completed correctly (left lock open) but partnering player B made a mistake (right lock shows a red cross). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

is intrinsically embedded in the cooperative design since one player's error will compromise the high score the team can attain. Moreover, since the next question is only given when both players complete their selection, the reaction time of the slowest player has the most influence on the high score the team can achieve in 90 s. Peer accountability is also made visibly explicit to the players through the display of two open locks animation and "red cross" error indicator.

3.3. Procedure

Three modes were investigated in this experiment, as shown in Fig. 2. There was the single *competitive mode* shown in Fig. 2(a) and the two cooperative modes, both with the same gameplay mechanics except for the physical arrangements of the two partners. The first is *cooperative mode - apart* and the other is *cooperative mode – close*, as shown in Fig. 2(b) and (c) respectively. The 40 participants formed 20 team pairs. Within-subject design was used with the teams playing three different modes in counter-balanced order. On arrival at the laboratory, the participants filled out a consent form and answered some profiling questions before the facilitator started the experiment. Firstly, there was an individual practice session which allowed the participants to familiarize themselves with the Stroop test task. In this practice session, the participants were required to finish ten questions correctly. After the practice session, the participants were asked if they needed more practice. If not, they started the formal experiment where the participants did three sessions using their assigned order. Each session consisted of two rounds of 90 s duration gameplay. Before the cooperative gameplay session, there was also an additional practice round to help players understand the cooperative gameplay design.

Participants also answered two different survey questionnaires, one per in-between sessions rest period and in the sequence dependent on their counter-balanced order. They were asked to rate their effort, focus and preference as soon as they were able to compare the competitive-vs-cooperative modes or the apart-vs-close proximity modes. Written feedback and comments were also collected.

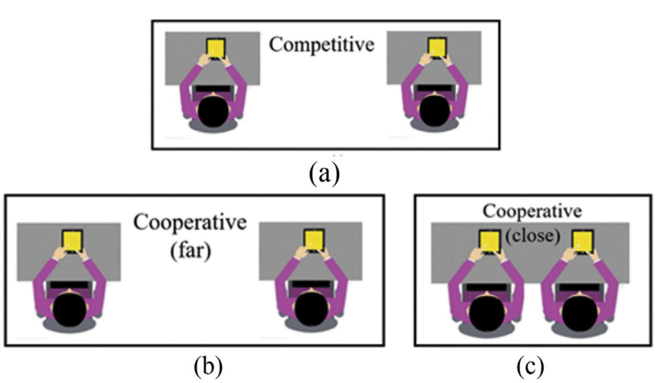

Fig. 2. The three modes: (a) competitive mode, (b) cooperative mode – apart, (c) cooperative mode – close.

3.4. Measures

There are two common performance parameters used in studies that employ the Stroop test to measure a subject's attention level or ability. The Stroop effect is a demonstration of interference in the reaction time of performing a Stroop task. As such, a subject's reaction time during a Stroop test is widely used to gauge performance. The other is the number of erroneous selection made during the series of Stroop tests. For example, both time and error related measures in the Stroop color-word test was successfully used to discriminate between children with fetal alcohol syndrome and healthy children (Mattson, Goodman, Caine, Delis, & Riley, 1999).

In our study, the reaction time and error rate were both used to measure the attention level. Reaction time is defined as *the time lapsed from the question presented to the question being answered*. And error rate is defined as *the ratio of the number of incorrect answers to the number all the answers completed.* Players who do not pay attention to the task is expected to take a longer time to complete the task and is more likely to make mistakes than when they are focused on the task at hand.

The game score, which counts the number of correct answers completed in 90 s is actually a performance measure that combines the influence of both the reaction time and error rate. Unfortunately this measure cannot be used in our analysis because in the cooperative mode, partners need to wait for each other in order to progress in the game thus providing unfair performance advantage to the individual competitive mode. However, individual reaction time in the cooperative mode is independent of the partner's performance as it does not include the waiting time. It is therefore a more accurate measure of a player's attention level in both modes of gameplay. Cooperative mode error rates are also individual performance measures as the system records the answers each player chooses independently. Their erroneous selection only affects the team's progress in the game but not the team mate's own choice.

4. Data analysis and results

4.1. Competitive mode versus cooperative mode

Research findings have shown that compared to individual gameplay, competitive play and cooperative play can lead to higher level of engagement. However, results comparing competitive and cooperative gameplay have been mixed (Peng & Hsieh, 2012; Plass et al., 2013; Siu et al., 2014). In this study, we ask the following research questions:

RQ1. *Which multiplayer gameplay mode, competitive or cooperative, results in higher level of attention in a cognitive task?*

To answer this question, each player's performance in each gameplay mode in terms of error rate and average reaction time was computed. Then paired *t*-test was used to compare the results from the competitive mode and the cooperative mode - apart in order to maintain the physical arrangement attribute constant. The differences in error rates between the competitive and cooperative modes are significant, ($t(39) = 2.673$, $p = 0.011$, $d = 0.432$). Participants made relatively less errors during cooperation ($M = 2.20\%$, $SD = 3.40\%$), than during competition ($M = 3.23\%$, $SD = 4.35\%$).

Intuitively, the reduced error rates are expected to be achieved at the expense of slower reaction time. However, there was no significant difference between the reaction times in the competitive and cooperative modes, ($t(39) = 1.262$, $p = 0.215$, $d = 0.120$). In fact, the average reaction time in the cooperative mode ($M = 1.049$, $SD = 0.119$) is even lower compared to that in the competitive mode ($M = 1.083$, $SD = 0.219$). In other words, the cooperative mode actually led players to make fewer errors without slowing down their response time. In performing a task like the Stroop test, this implies more cognitive effort and focus were being employed by the players during cooperation.

4.2. Temporal performance changes

Previous analysis used the average reaction times and error rates to analyze the attention level for the entire game duration. Besides the overall attention levels, we are also interested in the players' ability to sustain attention during gameplay. To this end, we investigated the following research questions:

RQ2. *Is there any difference between the attention levels at the starting and ending stages of the game? And if so, how does it differ in the different gameplay modes (competitive vs. cooperative)?*

To answer this question, the average performance measures at the start of the game (first 20% responses) were compared with those at the end of the game (last 20% responses). A two-factor (game stage × gameplay) repeated measures ANOVA was used in this study for the reaction time. A main effect of game stage was found ($F(1,39) = 14.881$, $p < 0.001$, $\eta^2 = 0.276$). No main effects of gameplay mode or any interactions were observed (all $p > 0.08$). Follow-up paired t-tests on main effect of game stage show that the reaction times increased from the start stage ($M = 1.035$, $SD = 0.186$) to the end stage ($M = 1.083$, $SD = 0.174$) in the cooperative modes ($t(39) = -3.248$, $p = 0.002$, $d = -0.514$). In contrast, the change of average reaction times in the competitive mode was not significant ($t(39) = -1.242$, $p = 0.222$, $d = -0.196$), with ($M = 1.060$, $SD = 0.194$) at the start to ($M = 1.080$, $SD = 0.211$) at the end. These results suggest that the temporal performance decline occurred only in cooperative mode but not in the competitive mode.

4.3. Faster and slower players

A common feature in cooperative settings is the differences in general performance levels among the partners. Some can be faster at the task than others. Group role, that is, being the faster or the slower player in the group may be a factor that can impact the player's focus and effort, since the need to cooperate can stir up different types of feelings among players with different group roles. Faster players may feel impatient waiting for their slower partners whilst the slower counterpart may feel pressured and anxious. We are therefore interested to answer the following research question:

RQ3. *Will group role (i.e. the faster or slower players) affect attention level in competitive and cooperative modes?*

Adopting the group role notion, the players in each group pair were identified as the faster or slower player based on their respective average reaction time during the competitive mode, as seen in Fig. 3. The performances of the faster and slower players during cooperation were separately investigated. The two-factor mixed analysis of variance (ANOVA) with group role types (faster vs. slower players) as between-subject independent variable and gameplay modes (competitive vs. cooperative) as within-subject independent variable was conducted for error rate and reaction time.

Regarding error rate, there was a main effect of gameplay modes ($F(1,38) = 7.967$, $p = 0.008$, $\eta^2 = 0.173$) found, but no main effect of

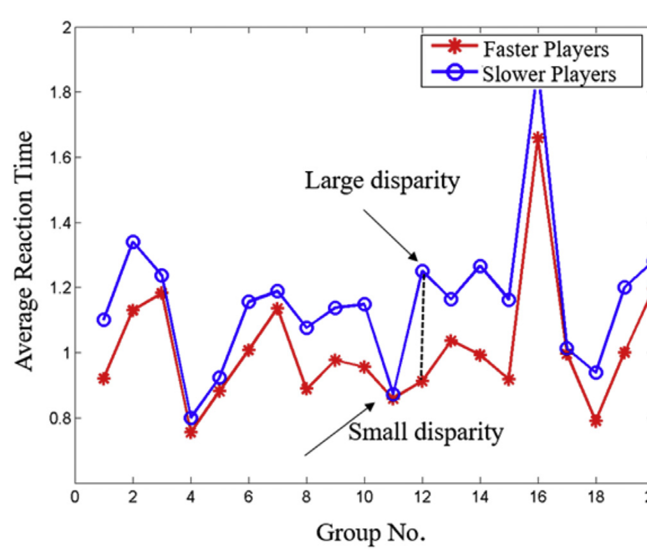

Fig. 3. Identification of a player's group role using average reaction time during competitive gameplay. Examples of pairs with large and small average reaction time disparities are group numbers 12 and 11 respectively.

group role ($F(1,38) = 2.584$, $p = 0.116$, $\eta^2 = 0.064$) or interaction effect ($F(1,38) = 3.204$, $p = 0.081$, $\eta^2 = 0.078$) were observed. Follow-up paired t-tests were performed to examine the main effect of gameplay modes for error rate in more detail. The results show that for faster players, there was no significant difference in error rate between the competitive ($M = 1.98\%$, $SD = 1.62\%$) and cooperative gameplay ($M = 1.61\%$, $SD = 2.17\%$) modes, ($t(19) = 0.951$, $p = 0.354$, $d = 0.213$). However, the slower players made significantly fewer errors in the cooperative mode ($M = 2.78\%$, $SD = 4.28\%$) than in the competitive mode ($M = 4.48\%$, $SD = 5.74\%$), ($t(19) = 2.628$, $p = 0.016$, $d = 0.588$). When it came to reaction time, a main effect of group role ($F(1,38) = 5.860$, $p = 0.020$, $\eta^2 = 0.134$) was observed as expected, but no significant main effect of gameplay modes ($F(1,38) = 1.625$, $p = 0.210$, $\eta^2 = 0.041$) or interaction effects ($F(1,38) = 1.798$, $p = 0.188$, $\eta^2 = 0.045$) were observed. Paired *t*-test also revealed that there was no significant difference in reaction time between the competitive and cooperative modes for both faster players ($M = 1.010$ to 1.011, $SD = 0.194$ to 0.119, $t(19) = -0.051$, $p = 0.960$, $d = -0.011$) and slower players ($M = 1.157$ to 1.087, $SD = 0.222$ to 0.109, $t(19) = 1.712$, $p = 0.103$, $d = 0.383$). These findings imply that cooperation can help the slower players improve their accuracy in the cognitive task and this improvement is not at the expense of the faster players' performance.

We also did another analysis to examine the temporal performance changes for the faster and slower players. Paired *t*-test revealed that in the cooperative mode, the temporal degradation of reaction times were significant for both the faster players ($M = 0.978$ to 1.034, $SD = 0.127$ to 0.132, $t(19) = -2.654$, $p = 0.016$, $d = -0.593$), and slower players ($M = 1.042$ to 1.108, $SD = 0.113$ to 0.126, $t(19) = -3.204$, $p = 0.005$, $d = -0.716$). However, in the competitive mode, there was again no significant decline in reaction time for both the faster players ($M = 1.014$ to 1.021, $SD = 0.194$ to 0.223, $t(19) = -0.387$, $p = 0.703$, $d = -0.087$) and slower players ($M = 1.106$ to 1.139, $SD = 0.187$ to 0.185, $t(19) = -1.248$, $p = 0.227$, $d = -0.279$). These results suggest that the players' performance in terms of reaction time degraded over time during cooperative gameplay. And this degradation occurred for both the faster and slower players. Fatigue could be a possible explanation if not for the fact that this temporal performance degradation should be equally applicable during competitive gameplay but is not significantly present. Some other factors could be at play here.

4.4. Large and small performance disparity

An interesting question to ask is what aspects of cooperative gameplay could cause the observed temporal performance decline. One possible reason is the performance disparity between partnering pairs. If the average reaction time between the faster and slower player is large, then the faster player is frequently waiting for the partner to finish and may feel bored. On the other hand, the slower player may feel nervous and pressured when the partner's lock repeatedly opens way before he is able to answer. Sustained boredom and anxiety could both impair focus and exert a negative effect on the player's attention level, leading to declining performance with time. Based on this speculation, we explore an additional research question:

RQ4. *Will performance disparity between partners affect temporal performance during cooperation?*

The performance disparity for a group is defined as the absolute difference between the average reaction time of two players during competitive gameplay. This disparity between partners can vary significantly, as seen in Fig. 3. Performance disparity in the pair in group 12 is very large whilst that in group 11 is negligible. In order to answer research question RQ4, all 20 group pairs were sorted based on increasing performance disparity, as shown in Fig. 4. The temporal performance degradations of the groups with large performance disparities (top 40%) were compared with that of the groups with small performance disparities (bottom 40%). A 2 × 2 (performance disparity × game stage) mixed ANOVA was conducted for reaction time in cooperative mode - apart. Only a main effect of game stages was found ($F(1,30) = 8.042$, $p = 0.008$, $\eta^2 = 0.211$). No other main effect ($F(1,30) = 0.289$, $p = 0.595$, $\eta^2 = 0.010$) or interaction effect ($F(1,30) = 0.860$, $p = 0.361$, $\eta^2 = 0.028$) were observed. Follow-up paired t-tests were performed to examine the main effect of game stage for large and small disparity groups in more detail. For those groups with large performance disparity, paired *t*-test suggested significant temporal performance decline occurred from the start stage ($M = 1.006$, $SD = 0.117$) to the end stage ($M = 1.064$, $SD = 0.136$), ($t(15) = -2.505$, $p = 0.024$, $d = -0.626$). Interestingly, for those groups with small performance disparity, such decline was not significant ($M = 0.997$ to 1.032, $SD = 0.112$ to 0.092, $t(15) = -1.559$, $p = 0.140$, $d = -0.390$). These results imply that the player's performance seems to degrade with time during cooperation only when there is a large mismatch in ability between partners in solving the given task in a timely fashion.

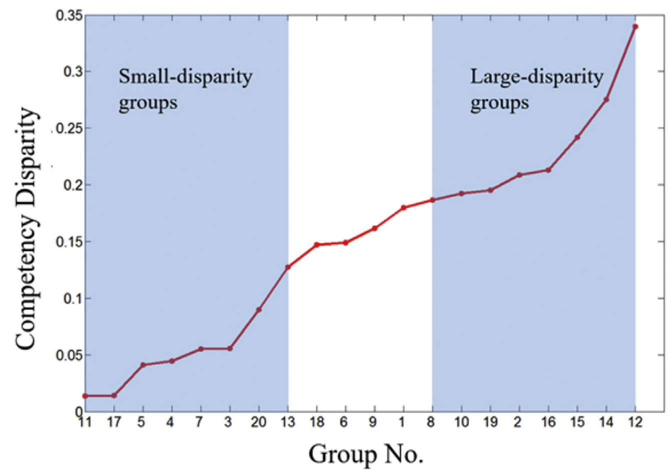

Fig. 4. Groups being sorted based on increasing performance disparity.

4.5. Close versus apart sitting arrangements

Research findings on proxemics show that interpersonal physical distance can influence the interaction between people (Jakobsen & Hornbæk, 2014; Mueller et al., 2014). In cooperative play, sitting in close proximity can create an environment that supports both verbal and non-verbal communications. As such, the potential for a stronger sense of cooperation and team morale is facilitated. There is however limited research examining the effects physical distances have during cooperative gameplay, especially those involving a cognitive task that requires focused attention. Therefore, we seek to answer the following research question:

RQ5. *How does physical proximity influence players' attention levels during cooperative gameplay?*

Paired *t*-test was used to compare the players' performance while cooperating in the close and apart sitting arrangements seen in Fig. 2(c) and (b), respectively. The *t*-test results revealed that there was no significant difference between the sitting apart ($M = 1.049$, $SD = 0.119$) and sitting close ($M = 1.065$, $SD = 0.170$) in terms of average reaction time ($t(39) = -1.029$, $p = 0.310$, $d = -0.163$). Similarly, in terms of error rate, there was also no significant difference found in sitting apart ($M = 2.20\%$, $SD = 3.40\%$) and sitting close ($M = 2.59\%$, $SD = 2.63\%$), ($t(39) = -1.080$, $p = 0.287$, $d = -0.171$).

In terms of temporal performance changes, a two-factor (game stage × sitting arrangement) repeated measures ANOVA were performed for the reaction time. Main effects of game stage were found ($F(1,39) = 27.332$, $p < 0.001$, $\eta^2 = 0.412$). No main effects of sitting arrangement or any interactions were observed (all $p > 0.08$). Similar to cooperative mode – apart, follow-up paired *t*-test shows that the reaction times also increased in the cooperative mode - close ($t(39) = -4.187$, $p < 0.001$, $d = -0.662$) from the start stage ($M = 1.010$, $SD = 0.123$) to the end stage ($M = 1.071$, $SD = 0.133$). Moreover, this temporal performance degradation was again significant for both the faster players ($M = 0.999$ to 1.038, $SD = 0.184$ to 0.178, $t(19) = -2.219$, $p = 0.039$, $d = -0.496$) and slower players ($M = 1.071$ to 1.127, $SD = 0.185$ to 0.162, $t(19) = -2.366$, $p = 0.029$, $d = -0.529$). These results suggest that the temporal performance decline occurred in cooperative mode regardless of sitting arrangements or group roles, but not in the competitive mode.

5. Discussion

This study examined the influence of peer accountability on players' gameplay behavior, in particular their attention levels. Based on the cooperative design used, the results show that players made significantly fewer errors when they were cooperating than when they were competing against each other, suggesting that the sense of peer accountability during cooperative gameplay has improved their focus and attention in the cognitive task. However, our results differ from those of (Peng & Hsieh, 2012), where they observed no significant performance differences between cooperative and competitive goal structures. There are several major differences between these two studies that can help highlight the appropriate context in which our findings can be generalized.

The first is the nature of the gameplay task. They used a motor activity-centered task requiring players to pop as many balloons as possible on a computer screen within a given time. We used a cognitive task that requires players to focus on a stimulus and make a corresponding multiple-choice selection, and repeat this correctly as many times as possible within a given time. Our study used the simple Stroop Color-Word Interference test and tertiary-level student participants in order to reduce the influence of task competency and content knowledge on the players' ability to perform the cognitive task. In this way, the performance is predominantly based of the players' ability to focus their attention during gameplay. Using complex cognitive tasks such as those involving arithmetic skills have resulted in contrary results which show competitive and not cooperative mode producing increased game performance relative to individual gameplay (Plass et al., 2013). Past research has shown that the impact of cooperation varies with the type of task employed. For example, cooperation has a positive influence on conceptual knowledge acquisition by promoting mutual elaboration, while no positive effect on skills acquisition was found (Mullins et al., 2011). Our study adds to these findings by showing that cooperation can also benefit cognitive tasks that require focus and selective attention.

The second is the extent of the peer accountability incorporated into the cooperative game design. Our study emphasizes explicit and strong peer accountability by ensuring one's progress in the game is peer dependent and all players' current performance is mutually visible, as illustrated in Fig. 1(b). In this conjunctive design of the cooperative play, the participants were made aware that they were simultaneously attending to the same task as their partner and this can evoke awareness of shared attention. Based the shared attention theory, people devoted more cognitive resources to tasks that are thought to be synchronously co-attended with another (Shteynberg, 2015; Shteynberg et al., 2014). In contrast, the cooperative game design of the balloon popping game uses implicit or weak peer accountability as the team score is essentially the combined score of each individual's independent effort during the cooperative gameplay (Peng & Hsieh, 2012). Our results suggest that performance improvement in terms of reduce error rates during cooperation may only be applicable to cooperative designs with strong peer accountability. However, it remains to be investigated if similar positive results for cooperation can be observed if we employed weak peer accountability in our cooperative game design, similar to those of (Peng & Hsieh, 2012).

Interestingly, more accurate performance does not necessarily translate to a more positive gameplay experience. Players' preferences for the two gameplay modes compiled from the questionnaire survey show a more mixed result, as shown in Fig. 5. Although there were more players preferring the cooperative mode ($N = 18$) than the competitive mode ($N = 11$), there were still 11 players who held neutral feelings. A sampling of comments from participants may provide further insights. Some players expressed they were motivated by the responsibility to the partners during cooperation, such as "*Competing as a team provokes my desire to win for the consideration of other team members*", "*I felt more responsibility to win the game as a part of team*", "*Competing as a team makes me feel greater sense of confidence and I hold the feeling of not wanting to disappoint the other member*". However, other players alluded to the loss of control and the increased stress introduced by the peer accountability "*Playing as individual is easier*", "*The response of the game to my answer is not as timely as that in competing individually*", "*Competing as a team increase the responsibility greatly, along with it I feel more stressful. I prefer to work individually*". These mixed preferences could be the result of the strong peer accountability employed in our game design. This can make players feel more motivated because of the strong sense of interdependency and teamwork. But it can also make some feel more nervous and conscientious about their own performance. Field dependent/field independent (FD/FI) cognitive styles of each individual may also explain the mixed preferences observed in our study. The FD/FI dimensions (Witkin & Goodenough, 1980) do categories people into those that prefer group and cooperative activities (i.e. FD) and those who prefer individualistic and competitive activities (i.e. FI).

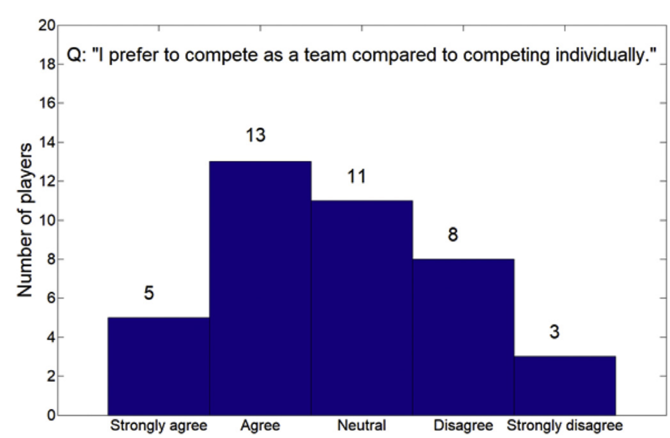

Fig. 5. Qualitative results from a 5-point Likert scale survey question asking players to compare their preference for the two gameplay modes. The numbers selecting the respective response are indicated above each bar plot.

Peer accountability appears to have a more positive influence on the performance of the slower players than the faster players. The slower players made significantly fewer errors when cooperating than when competing with their faster partners. The fact that these slower players can further improve their accuracy during cooperation suggests that being accountable to a superior or faster partner can create a strong incentive to put in more effort and focus. This observed phenomenon is reminiscent of Lev Vygotsky's view that interaction with more skilled peers is an effective way for less competent learners to develop skills and mastery (Vygotsky, 1978). Even though his theories are related to social learning, the benefits of cooperation with a stronger peer seem to be applicable to multiplayer gameplay too. More pertinently, our findings mirror that of the Köhler motivation gain effect, first described in the 1920s by Otto Köhler, a German industrial psychologist (Köhler, 1926, 1927). He observed that the weaker member of a group will exert extra effort that is beyond the usual performance limits when paired with a stronger partner in a conjunctive task. Such tasks are similar to the cooperative task with strong peer accountability used in our study, where the group's productivity or performance is equal to that of the weakest member. Several social-psychological mechanisms have been suggested to explain this phenomenon (Kerr & Hertel, 2011). One is the social comparison process that encourages one's personal performance goals to be revised upwards when working with a more capable partner as one becomes aware of a higher performance standard. Another is the player's sense of indispensability to the group. The more indispensable one perceives one's effort is to the group's outcome, the greater the effort one will exert. This is normally associated with the feelings of not wanting to let the team down. It is interesting to note that most studies related to the Köhler motivation gain effect have been described in the context of physical activities such a rowing, tethered mountain climbing and exergaming (Hertel, Kerr, & Messé, 2000; Irwin, Scorniaenchi, Kerr, Eisenmann, & Feltz, 2012; Messé, Hertel, Kerr, Lount Jr, & Park, 2002). However, our study has provided empirical support that this effect is equally applicable to a cognitive conjunctive task. This implies that the Köhler motivation gain effect can also be employed to motivate and pull up the "weaker link" in cooperative activities requiring focus and attention, not just physical effort.

The dynamics of cooperation between unequal partners appears to be more complicated than it first appears. The influence of peer accountability on player's behavior is not always positive. Our analysis of average in-game reaction time data shows that cooperating partners who have highly mismatched competencies are unable to sustain their performance. There was a significant degradation in their average reaction time by the end of the gameplay duration but this temporal slowdown was not frequently observed with closely-matched pairs. Similar negative side effects in cooperation were observed by researchers studying the impact of team ability disparity playing a Counter-Strike game (Yuan et al., 2016). They found that under a cooperative reward structure, playing in a team with high ability disparity had a negative influence on individual performance. Interestingly, Köhler also observed that the amount of motivation gains is dependent on the extent of discrepancy between partners' abilities (Köhler, 1926, 1927). The Köhler discrepancy effect suggests that there is an optimal ability disparity that can encourage the weaker player to improve but when this disparity is too large, the motivation gain will start to decrease. The sense of indispensability when presented in a highly mismatched group can create high stress and in turn affect sustained performance. This was indeed reflected by some of the comments in the questionnaire survey such as "*Competing as a team gave me more pressure. I can't do anything wrong as I need to be responsible for my partner*". It is unclear if this observed behavior can be generalized to other types of cooperative activity designs such as those that have weaker peer accountability or when the ability disparity is measured by other dimensions besides average reaction time. Nonetheless, this finding provides further support of the relevance of the Köhler discrepancy effect in attention-based cognitive task and its implications on how optimal teams should be formed. Where possible, it is a prudent strategy to ensure the abilities of team members are not severely mismatched if one hopes to sustain good teamwork performance.

Lastly, there are numerous studies on the social and cognitive affordances of spatial features such as distance, proxemics, co-presence and physical visibility of shared context (Nova, 2005). The influence of close proximity has been associated with positive emotional, cognitive and behavioral changes in work groups (Kiesler & Cummings, 2002). However, our study comparing sitting arrangements during cooperative gameplay shows that physical proximity does not have any significant positive influence on players' performance when they are cooperating over a task that required each individual's sustained attention and cognitive focus. This result is not surprising when we consider the fact that the cooperative Stroop test task used in our study can be accomplished with minimal communication and consultation between partners. As such, it is not representative of typical cooperative tasks where the positive effects of conversation (Clark & Brennan, 1991), task and group awareness (Dourish & Bellotti, 1992) can be facilitated by physical proximity. From our user survey, it appears that people are psychologically affected in different ways when they cooperate in close proximity. Some players were affected positively and shared comments such as "*I was more focused because my teammate was sitting beside me*" and "*when sitting close, the sense of working in a team is stronger*". However others felt increased pressure and distraction. They shared that "*sitting close brings pressure*" and "*sitting further from my partner decreases the distraction, thus I was more focus*". In short, we observed that when cooperating over a task that required focused attention, close physical proximity did not always bring positive influence but might create undesirable distractions.

6. Limitations and future work

There are several limitations in the generalizability of the findings in this work. Most notably, the simple cognitive-oriented Stroop task used in the multiplayer gameplay design is not representative of typical video games, which usually incorporate many complex gameplay and cooperative elements. Our goal to focus predominantly on the influence of peer accountability is most representative of the commonly used cooperative design pattern called complementarity (Rocha, Mascarenhas, & Prada, 2008; Seif El-Nasr et al., 2010), which refers to mechanism that gives players the abilities to complement each other's activities. In our design, the left lock complementing with the right lock determines whether the players can successfully get the point and move to next question. Similar applications of such design feature can be found in First Person Shooters (FPS) games. For example, to reach higher grounds, players need to come to the spot together and piggy back on each other (Rocha et al., 2008). Like our design, the progress of the team is also dependent on the cooperative contribution. Our results might shed some light on the dynamics between faster and slower players as well as the influence of their performance disparity in this specific case. However, besides complementarity, many other cooperative design features are often employed and intertwined with each other in typical video games. For example, video games with more complex character designs can support synergies between abilities (Rocha et al., 2008; Seif El-Nasr et al., 2010) to allow one character type to assist or change the abilities of another. Our findings may not be generalizable to such complex multiplayer game design scenarios. Further research is needed to study how different cooperative design patterns and the combination of them may affect players' attention in more realistic video game settings. However, the challenge of such an endeavor is to be able to account and assign the measured influence to the different cooperative design elements as mutual interactions cannot be avoided.

In addition, we employed a simple cognitive task in the form of a Stroop test in order to allow us to measure attention levels using basic quantitative measures such as response time and error rates. However, real-life cooperative applications involving problem solving and complex decision making often require higher levels of cognitive skills. Under such scenarios, players could exhibit very different interaction dynamics and cognitive states during competition and cooperation. Studies employing more challenging cognitive tasks such as multiple-choice-multiple-answer questions and more sophisticated measures of player performance would be needed to further explore this comparative investigation using higher cognitive skill sets.

7. Conclusions

Our study provides quantitative empirical support for the positive influence of peer accountability on attention levels in conjunctive cognitive task. The implication of these findings for game or collaborative application designers is that one can employ a cooperative design with strong peer accountability to increase players' attention and performance in terms of accuracy. Unfortunately, for some players, this performance improvement can be accompanied by a less positive gameplay experience in terms of increase peer pressure and loss of personal control. This study also provides further evidence to support the Köhler motivation gain and Köhler discrepancy effects. Our results show that the Köhler effects are equally applicable to cognitive-oriented cooperative tasks as they are to physically-oriented ones. Peer accountability is a good way of getting more superior members to motivate improved performance from the rest of the team but the discrepancy between the members' abilities must be properly moderated to maintain such positive scaffolded gains. Lastly, physical proximity was observed in our study to have mixed effects on players and was not seen to have any significant positive influence on cooperating players' performance in cognitive tasks requiring focused attention.

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