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Natural Mapping and Intuitive Interaction in Videogames

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ABSTRACT
Videogame control interfaces continue to evolve beyond their traditional roots, with devices encouraging more natural forms of interaction growing in number and pervasiveness. Yet little is known about their true potential for intuitive use. This paper proposes methods to leverage existing intuitive interaction theory for games research, specifically by examining different types of naturally mapped control interfaces for videogames using new measures for previous player experience. Three commercial control devices for a racing game were categorised using an existing typology, according to how the interface maps physical control inputs with the virtual gameplay actions. The devices were then used in a within-groups (n=64) experimental design aimed at measuring differences in intuitive use outcomes. Results from mixed design ANOVA are discussed, along with implications for the field.

Author Keywords
Intuitive Interaction; Game Control; Natural Mapping; Control Devices; Games User Research.

ACM Classification Keywords

INTRODUCTION
The growing study of intuitive interaction with user interfaces offers definitions for intuition, means to measure occurrence of intuitive interaction, and guidelines for designers to maximise their interface's potential for intuitive use. The focus of research in this field has largely been on interfaces with a utilitarian purpose, and application of these techniques to evaluate the intuitive potential of interfaces for systems with other purposes, such as videogames, is not available in the current literature. This is despite the fact that motion control and tangible interfaces for games are becoming more pervasive, are often claimed to be ‘intuitive’ [8, 11, 18, 19, 20], and the accessibility of these interfaces has been identified as one of the key drivers for growth in the industry [21, 23]. These control devices employ natural mapping to leverage embodied knowledge by capturing control actions that mimic the simulated real-life activity. This offers players the chance to bypass the expertise requirements usually demanded to execute challenging virtual control actions with traditional interfaces. While it appears these interfaces use natural mapping to broaden their accessibility and enable a higher potential for intuitive use, these assumptions have yet to be empirically tested. This paper seeks to verify these claims by applying and adapting existing intuitive interaction theory and tools to evaluate naturally mapped control interfaces (NMCIs) for videogames. It presents newly developed instruments to measure intuitive potential and fulfilment, which were applied in an experiment that examined the intuitive use outcomes for players using three different types of NMCIs with a racing videogame.

Naturally Mapped Control Interfaces for Videogames
Naturally mapped control interfaces (NMCIs) for videogames involve interactions with less abstraction between the task to be virtually achieved and the action required to achieve it. As such it is hypothesised that these control interfaces are more accessible, provide the potential for more nuanced virtual control, and remove barriers to enjoyment of the game [2, 9, 21]. Additionally, if the interface mapping (and the supportive technology) is strong enough players should be able to achieve much more freedom in how they execute control actions, with potentially a much finer degree of control than with a traditional controller. In theory, the barriers to performing well in a game move from mastery of a control device to the mastery of one’s own actions as relevant to the game mechanics. For example, making the main game character swing a sword a particular way should be easier to remember, provide greater proprioceptive feedback, and be more satisfying to perform if the player physically swings a control wand (like the Playstation Move) the way the player wants the character to do it rather than having to recall and execute specific stick and button combinations.

Early research on NMCIs for videogames focused on the performance impacts and player preferences for natural controllers and peripherals [8, 11, 14]. Recently the impact of different NMCIs on the player experience has also started to be explored more widely [1, 3, 9, 12, 13, 20, 21].
Generally, researchers have found that more naturally mapped interfaces provide a greater response to some play experience measures, particularly measures related to game engagement such as presence and flow [1, 3, 9, 13, 20, 21]. Broad measures for enjoyment have also been positively linked with the use of NMCIs as compared to traditional interfaces [2, 3, 14, 20], yet some research challenges this claim [12]. The youth of this field of research, however, inevitably leads to discrepancies in experimental approach and control. For instance, due to the limited field of available commercial products to test some studies test games and controllers across different platforms, limiting their ability to directly compare conditions [12]. Attempts to address this have been made by developing custom game environments for testing [3, 9], yet this requires greater investment and development skills and raises additional questions around ecological validity. There is also inconsistency of approach in terms of how to measure a player’s previous experience and whether to consider exposure to the equivalent real-life activities that are being naturally mapped. Some researchers use measures such as hours of play with the tested game or videogames generally [7, 9, 11, 14, 21], while some ask participants to select from broad categories [3, 8, 9, 12]. Examples of the equivalent real-life activity being measured are limited and also vary in approach [8, 12, 20]. Work in this field initially only broadly categorised NMCIs types, grouping all NMCIs together using terms such as ‘natural’ or ‘realistic’ when comparing them to their ‘non-natural’ counterparts [7, 11, 14, 20]. The level of body motion required to interact with the interface has been used as a defining factor in some research [2, 15, 16], and has been applied in defining NMCIs along with the social context of use [1, 2, 15, 16].

Skalski et al. [21] also examined perceived enjoyment and preference for NMCIs, yet helped explicate differences between different types of NMCIs and traditional controls by developing an initial typology of NMCIs for videogames. The typology consists of four categories of natural mapping: directional, kinesic, incomplete tangible, and realistic tangible. Directional natural mapping occurs when there is a ‘correspondence’ with direction between physical control and virtual result, such as when a control stick makes a character turn left when pushed left. Kinesic natural mapping occurs when natural body movements are captured and translated into equivalent actions in the game space without a tangible component (for example, making a kicking motion in the real world in order to kick a ball in the virtual world). Incomplete tangible natural mapping is when the player is provided with a physical object to manipulate that ‘partially simulates’ the form and function of the equivalent virtual object, such as with using the Wii Remote as a tennis racket. Realistic tangible natural mapping takes place when the tangible object looks, feels and responds like the virtual object in the real world, such as a spring loaded leather-bound racing wheel controller. Skalski et al. [21] admit this typology is only starting to explicate the variables around control mapping in games, and suggest its use as a starting point for further research. They highlight that types may overlap in a single control device, which means an NMCI type is defined by a specific instance of mapping of control actions between a control device and a game.

The hypotheses of Skalski et al.’s [21] research are that the realistic and tangible NMCIs will sit at the top of the scale of perceived controller naturalness, provide a greater sense of spatial presence, and in turn predict videogame enjoyment. To confirm their hypotheses, controllers falling into different categories in the typology were tested for both a racing and a golf game. While the relationship with enjoyment was not confirmed, NMCI types were found to powerfully modify responses to videogames as otherwise predicted. Additional validation of the NMCI typology has been published [9, 13], with Cairns et al. [9] examining the effects of NMCI type on immersion in mobile games. Here Skalski et al.’s hypotheses are again broadly confirmed, with more naturally mapped control types generally leading to greater immersion. Yet more research is needed to clarify the definition and broader play experience impacts of NMCIs [9, 21], both across genres/platforms and for different player groups.

**Intuitive Interaction**

The source of knowledge for an intuitive action can be difficult to identify, yet two groups of researchers building on decades of research and theory in cognitive science have helped tie intuition to previous experience [4, 6, 10, 17]. According to these researchers, intuition is the end result of a cognitive process that matches current stimuli with a store of amalgamated experiential knowledge, built up through time in similar situations. Strictly speaking, a device or interface is not ‘intuitive’ in and of itself, however, the information processing applied to it can be [6]. Intuitive interactions should also be, at least subjectively, the correct action in the context of use and can be much faster due to the increased speed of subconscious rather than analytical processing. It is for these reasons that response time and accuracy are common measures for intuitive interaction [6].

A product can have a high potential for intuitive use if it is designed to take advantage of experiential knowledge that is broadly possessed by its target audience. The two groups of intuitive interaction researchers developed distinct theory about the types of experiential knowledge accessed during intuitive interaction, and how designers could maximise an interface's potential for intuitive use. Yet there is significant overlap between these two models. The German-based Intuitive Use of User Interfaces (IUUI) Research Group presented a 'continuum of knowledge in intuitive interaction' (shown as the upper square in Figure 1) with types of experiential knowledge accessed during intuitive interaction based upon their frequency of cognitive encoding and retrieval [10]. Blackler's intuitive interaction continuum suggested the means by which intuitive use can
be supported in product design [6], and is shown in Figure 1 as it relates to IUUI’s continuum. In IUUI’s continuum the most basic and broadly possessed knowledge identified is innate knowledge, which has genetic origins and manifests in responses such as reflexes. In Blackler’s continuum the most accessible design strategy is to use physical affordances, which take advantage of embodied knowledge of the world established early in life. This fits within IUUI’s sensorimotor level, which also includes knowledge applied during basic analytical processes (such as determining direction or identifying faces). Blackler classes the next level of knowledge as population stereotype, which relates to IUUI’s culture and sensorimotor levels and includes knowledge broadly possessed yet limited by societal bounds (such as different meanings for hand gestures between cultures). The level with the lowest frequency of encoding and retrieval in IUUI’s continuum is expertise, which is knowledge held only by those adept at a particular speciality (such as the knowledge a programmer uses to code a game). To enable intuitive interaction for this group Blacker suggests using familiar features from the same domain, yet if unavailable the designer may have to leverage familiar features from another domain. If the technology or context of use is completely new then designers can leverage metaphor to communicate the intended interaction protocol. In this way both research groups highlighted how targeting different types of knowledge in the design of an interface might modify the potential for intuitive use.

Blackler also devised the Technology Familiarity (TF) questionnaire as a tool to quantify the relevant experience of users that may contribute to intuitive use with a particular interface. This survey compiled a range of products and interfaces with similar features to the device being studied and asked participants to rate how often they have used them and how many of the features they used. Responses were then given a score (with greater frequency and breadth of use receiving higher scores) and tallied to determine the user’s TF score for that device. In four experiments focusing on interfaces from microwaves, universal remote controls and a digital camera, where the percentage of intuitive uses was established through codified observational measures, Blackler found significant correlations between TF scores and percentage of intuitive uses as well as other measures such as correct uses and time to complete set tasks. Overall, Blackler was able to conclude that related amalgamated experiential knowledge, as measured by Technology Familiarity, is an accurate predictor for intuitive use [5]. In other words, an interface enables intuitive use if its design includes features that the intended users have had previous experience with.

In intuitive interaction research the focus has largely been on interfaces for functional interactive systems, where usability and efficiency have been given priority during evaluations. While games research into the impact of NMCI is diverse and growing, exploration of the role of NMCI in facilitating intuitive interaction is limited. Specifically, intuitive interaction theory, and its associated tools and measures, have not yet been applied in the games research space. This is despite ‘intuitive’ control devices being recognised as fundamental to play motivation and experience [19]. Since the main goal of videogames is to engage users in an emotionally motivating way (produce enjoyment through the application of skill to overcome challenge), the impact of control devices designed for intuitive interaction may extend beyond usability and efficiency gains into uncharted territory.

**METHOD**

The primary aims of the experiment presented here were to develop targeted measures of technology familiarity for videogames, and evaluate the intuitive interaction potential of different types of naturally mapped control interfaces (NMCI) for videogames for different demographic groups. Sixty-four participants (43 male) voluntarily took part in the within-groups study. The study was conducted with participants individually and took around one hour to complete. Participant age ranged from 17 to 76, with an average age of 29.7 years (SD = 10.5). Study recruitment methods included online social networking, personal and professional networking (in person and via email), and an announcement in a first year undergraduate computer games studies unit. The chance to win a $100 gift card was offered as a recruitment incentive to all participants.

**Manipulation**

Participants were asked to indicate their age bracket and on this basis were randomly assigned to a counterbalanced order of the study conditions – three control devices (shown in Figure 2) used for play sessions with *Forza Motorsport 4* (Turn 10 Studios, 2011), a racing game on Microsoft’s Xbox 360 gaming console. Each device had full native support within the main mode of the game and represented a distinct type from Skalski et al.’s typology of NMCI [21], as shown in Figure 2. The categorisation of the naturally mapped control device was thus determined by the NMCI type represented by the mapping between the

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Figure 1: The Intuitive Interaction Continua, adapted from [4]
physical and virtual representations of the main control actions for this specific game context. The Controller is the primary control device for the Xbox 360 games console (released 2006), and is recognised as a traditional control input. In this study players used the left analogue stick for steering, the right analogue trigger for accelerating, and the left analogue trigger for braking/reversing. The Controller was used as an example of a device with directional natural mapping, as only the direction of the player’s input is mapped to the in game action (e.g. pushing left on the control stick causes the car to turn left).

The SpeedWheel (Wireless Speed Wheel for Xbox 360, released by Microsoft in 2011) uses internal accelerometers to detect tilt manipulation. In this study players used tilt-based motion controls for steering, the right analogue trigger for accelerating, and the left analogue trigger for braking/reversing. The SpeedWheel is an example of incomplete tangible natural mapping as players manipulate the device like the real-life equivalent interface (i.e. turning the wheel to the right turns the car right), yet its U-shape only partially simulates the look and feel of a steering wheel and pedal motions are still assigned to analogue triggers. The RacingWheel (Xbox 360 Wireless Racing Wheel, released by Microsoft in 2006) features a leather-bound racing wheel with wired pedals. In this study players rotated the wheel for steering, and pressed down on the right analogue pedal for accelerating and the left analogue pedal for braking/reversing. The RacingWheel is an example of realistic tangible natural mapping because it is manipulated as if driving a real car and also simulates the look and feel of the real-life interface. The RacingWheel was mounted to a table that, along with the wired pedals, was moved in front of the seated participant and adjusted if necessary. The setting for the vibration and force feedback motors remained in the default state for all devices.

**Procedure**

Upon arrival at the laboratory participants were given a brief scripted verbal overview of how the study session was to be conducted. Following this, the demographics and Game Technology Familiarity (GTF) questionnaires were administered by the researcher as a guided online survey. The guided survey approach was utilised, as with previous applications of Technology Familiarity measurement [6], to ensure that all participants had the highest chance of fully understanding the questions being asked, many of which referred to very specific devices and technological features.

This section of the study concluded with participants filling in additional demographic details, and in total took between 5-15 minutes. Participants were then asked to play the racing game using their first assigned control device. To play the game participants were asked to sit approximately 2.5 metres in front of a 55-inch TV connected to the game console and screen recording equipment. The track and car selected within the game was the same for all study conditions - Fuji New Down Hill and the Seat Leon Supercup respectively. The track was chosen as it was linear and so offered a percentage complete score, as well as decreased learning effect between conditions (in comparison to a race in which the same lap was repeated multiple times) and required a good mix of control actions (accelerating, braking, and steering in both directions). The car was chosen as it offered a good balance between a racecar and a regular automobile (high acceleration and top speed yet also a reasonable level of handling).

Upon commencement of each experimental condition the researcher gave a limited overview of what participants could expect to encounter in the play session, including a description of the basic controls along with the objectives - to relax, have fun, and try to progress as far down the mountain as possible before the race was stopped. The participants were not informed exactly how long they would be racing for, and were not given any practice using the control devices. This was necessary to meet our experimental aim of measuring intuitive interaction, allowing us to assess how the participants were transferring their previous experience into playing the game rather than how quickly they could be trained to use the devices [6]. Once the participant confirmed their understanding the game screen was activated and the countdown to the start of the race began. After four minutes of race time the participant's progress through the course, represented in the game as a percentage complete score, was recorded and the screen was switched off. Participants were then asked to fill out an online play experience survey alone based on their time playing the game with the control device. Next, participants were asked to complete an interview regarding their experience using the control device. The interview took one to two minutes and captured qualitative data about participants’ likes and dislikes of using the device and whether the device worked as expected. Following the interview, participants were asked to play the race again with the next assigned control device and the above process was repeated for the second and third conditions. After the third interview regarding the device just used, an additional interview was undertaken that captured general feedback and device preferences before the study session was concluded.

**MEASURES**

**Demographics and Subjective Response**

The demographic questionnaire captured Gender and Age as well as items to gauge general gaming experience, such as...
as average hours per week spent gaming in the last year, most hours ever spent gaming in a single week, genre exposure and current play preferences. An 18 item version of the Player Experience of Need Satisfaction (PENS) instrument [19], with the Relatedness component removed, was completed after each condition. Initial descriptive analysis of some play experience measures has already been published [13], however statistical analysis of these measures are in preparation for publication. Analysis of the Intuitive Controls measure from PENS is included in this publication as a subjective measurement of the intuitive interaction potential of each control device as compared to objective measures such as Progress and Errors. The other play experience variables are withheld for later publication since they are less conceptually relevant to an examination of intuitive interaction in videogames. Intuitive Controls consists of three items and is high when the controls make sense and do not interfere with game involvement. An example item from Intuitive Controls is "When I wanted to do something in the game it was easy to remember the corresponding control". The PENS implementation asked participants to think about their time playing the game with each control device and rate their agreement on a seven-point Likert scale between '1-do not agree' and '7-strongly agree'. Item order for the PENS survey were independently randomised upon presentation to participants, and component scores calculated as the mean of its items.

**Game Technology Familiarity (GTF)**

The game technology familiarity (GTF) questionnaire is a new measure intended for application in the game control interface space that is adapted from the technology familiarity (TF) instrument developed by Blackler [6]. Four game technology familiarity (GTF) scores were calculated for each participant – one relating to their familiarity with each naturally-mapped control device type tested (‘Directional GTF’ relating to Controller familiarity, ‘Incomplete Tangible GTF’ relating to SpeedWheel familiarity, and ‘Realistic Tangible GTF’ relating to RacingWheel familiarity), and ‘RacePlay GTF’ relating to previous play with racing games. GTF scores are a weighted average of relevant item scores derived from participants’ pre-play indication of their degree of familiarity with the actual game and devices used in the experiment, and similar games, devices or device features. A ‘RaceLife familiarity’ score was also calculated that consisted of items relating to racing and driving a motorised wheel-controlled vehicle in real-life. For each GTF/familiarity item, three questions were asked: the initial and most recent time the participant used/did the item (to determine the approximate length of item exposure), and the peak frequency of item use/exposure. Scoring of question responses within each item were determined in a linear manner with escalating and proportional values assigned to the broad time categories that participants selected from. This approach to the design of question responses and scoring was adapted from the technology familiarity (TF) questionnaire, where time categories were broad (e.g. “at least once a week”) yet the scores for each category were not proportional to the temporal distance between them [6]. Each item score was calculated using the following formula, where \( T_i \) = ‘initial time used’, \( T_R \) = ‘most recent time used’, and \( F \) = ‘peak frequency of use’:

\[
GTF \text{ item score} = \left(\frac{T_i + 1}{T_R}\right) \times \left(\frac{2}{T_R}\right) \times F
\]

Full GTF metrics, including item contents and weights, along with justification for the final formula, are detailed in the supplementary materials. Question metrics were set consistently across all items so that calculation with the GTF formula ensured that no familiarity always equalled an item score of zero. The next possible smallest item score was 0.4 (if the participant only used the item more than 10 years ago and less often than every few months). The highest possible item score was 25 (if the item was initially used more than 10 years ago, most recently used in the last few days, and was used daily at the time the participant was using it the most). For the mixed ANOVA analysis presented in results the three GTF scores related to the control device conditions were converted into a percentage of their maximum potential score for each device. This was undertaken to enable a demographic analysis and repeated measures comparison between participant scores for each device, since the original GTF scores had different potential maximums that were logically limited by the temporal commercial availability of some of their items.

**Objective Measures for Intuitive Interaction**

Two measures were used to objectively assess the intuitiveness of each control interface, acting in place of traditional intuitive use measures such as time to complete set tasks, codified intuitive uses and accuracy [6]. The first measure, titled Progress, was the percentage of the race that was complete as shown on the game’s visual interface at four minutes through play in each condition. As the race was on a linear track, this represents the players’ progress towards their main goal – to race as far down the hill as possible before play was interrupted. The second measure aimed to assess intuitive interaction during play by counting the number of significant errors committed by the participant when using each control device to play the game. Errors were codified for each device post-play using observational analysis of videogame screen footage captured during play. This required errors to be visually apparent, representing substantial mistakes in judgement or performance that negatively impacted achievement of the in-game goal. Specifically, the errors count increased for participants when one of the following conditions was satisfied: the car spun around, flipped over or onto its side, stopped for no apparent reason, was put into reverse, or the player’s in-game point of view was changed). If part of the same event (i.e. if one error was causally linked to another) the combined event was only counted as one error. A coding scheme covering the types of errors identified is included in the supplementary materials.
RESULTS

A series of repeated measures analyses of variance (RM ANOVA) were conducted using 'Control Device' as the within-subjects factor. Age, RacePlay GTF and RaceLife familiarity were split into three groups for use as between-subject factors along with Gender. The between-subject factors were then individually used to conduct mixed design repeated measures ANOVA's with the dependent variables [Game Technology Familiarity device percentage scores (device GTF), Progress, Errors and perceived Intuitive Controls (pIC) from PENS]. Descriptive statistics (such as age ranges and gender percentages) for these between-subject factors and their groups, as well the full the mean and standard error results, are detailed in the supplementary materials. Wilks' Lambda and an alpha level of $p < .05$ was used as the significance test for the mixed ANOVA results, while a Bonferroni adjustment with the same alpha level was used for all multiple pairwise comparisons. An experiment-wise Bonferroni correction was not applied due to the exploratory nature of the study, and so results should be interpreted with some caution.

During data cleaning one score was removed from each condition of the Progress measure due to participants travelling the wrong direction for more than a few seconds. No other missing values required intervention as missing data was below the accepted threshold [22]. Assumptions of normality were satisfied as in all instances there are both more cases than dependent variables and more than 20 cases per cell [22]. The only exceptions were age and gender by Control Device for Progress, where only 17 and 18 cases remained in the oldest and female categories respectively after data cleaning. However, Progress was expected to be skewed in the population and on this basis no transformations of the variables were performed. Three outliers were identified manually for both device GTF and Progress, however they were retained in both cases on the basis that they did not cause differences in the results when transformed and were representative of real demographic groups in the broader population (males with high RacingWheel familiarity and older females respectively). Investigation of the assumption of homogeneity of variance and covariance matrices was violated for Progress and Errors with age and gender as between-subjects factors. Further analysis found that variance and covariance were higher for the oldest group and females, and so significant findings related to gender and age for Progress and Errors should be interpreted with caution [22]. Violations to the assumption of Sphericity are highlighted within each relevant dependent variable, and in all cases were corrected with Greenhouse-Geisser adjustments.

Device Game Technology Familiarity (GTF) percentage

In the mixed ANOVA results for the device Game Technology Familiarity (device GTF) percentage a significant main effect of Control Device on device GTF ($F(2, 122) = 56.8, p < .001, \eta^2_p = .482$), was qualified by interactions between Control Device and Age ($F(4, 122) = 6.39, p < .001, \eta^2_p = .173$) and Control Device and RacePlay GTF ($F(4, 122) = 5.91, p < .001, \eta^2_p = .162$) for device GTF. A significant between-subjects effect of Gender on device GTF ($F(1, 62) = 4.32, p < .05, \eta^2_p = .065$) was also revealed, such that males ($M = 21.7$) reported higher familiarity across devices than females ($M = 14.6$). No significant effects were shown for RaceLife familiarity.

For the interaction between Age and Control Device for device GTF (shown in Figure 3A) the youngest group showed significant differences between all devices, such that they reported significantly more familiarity with the Controller ($M = 40.5$) than they did with the SpeedWheel ($M = 32.8, p < .05$) or RacingWheel ($M = 8.71, p < .001$), and also significantly more familiarity with the SpeedWheel than the RacingWheel ($p < .001$). The middle age group reported significantly less familiarity with the RacingWheel ($M = 7.31$) than both the Controller ($M = 22, p < .001$) and SpeedWheel ($M = 22.7, p < .001$), while the oldest group only reported significantly less familiarity with the RacingWheel ($M = 6.17$) than the SpeedWheel ($M = 16.8, p < .01$). For the within-device results for Age, the youngest group reported significantly more familiarity with the SpeedWheel than the oldest group ($p < .01$), as well as significantly more familiarity with the Controller than both the middle ($p < .01$) and oldest ($p < .001$) Age groups. All other multiple pairwise comparisons for the effect of Age on device GTF percentage were non-significant.

For the interaction between RacePlay GTF and Control Device for device GTF (shown in Figure 3B), all groups had significantly more device familiarity with the SpeedWheel ($\text{LOW } M = 13.8, p < .05, \text{MEDIUM } M = 27.8, p < .001, \text{HIGH } M = 32.8, p < .001$) than the RacingWheel ($\text{LOW } M = 4.94, p < .05, \text{MEDIUM } M = 6.38, p < .001, \text{HIGH } M = 11.41, p < .001$). However, only the medium and high RacePlay GTF groups also reported significantly more familiarity with the Controller ($\text{MEDIUM } p < .01, \text{HIGH } p < .001$) and SpeedWheel ($\text{MEDIUM } p < .05, \text{HIGH } p < .001$) than the low group ($\text{CONTROLLER } M = 11.5$). For the RacingWheel, the high RacePlay GTF group showed more familiarity than the both the medium ($p < .05$) and low groups ($p < .01$). All other between and within device effects of RacePlay GTF on device GTF percentage were non-significant.

Progress

Results from the mixed ANOVA for Progress (race percentage complete at four minutes) revealed a main effect of Control Device on Progress ($F(2, 116) = 24.1, p < .001, \eta^2_p = .293$), that was qualified by a significant interaction between Age and Control Device ($F(4, 116) = 2.46, p < .05, \eta^2_p = .078$). While no significant interactions were found for
the other between-subject factors, significant between-subject factor effects were revealed for both Gender ($F(1, 59) = 13.9, p < .001, \eta^2_p = .19$) and RacePlay GTF ($F(2, 58) = 9.78, p < .001, \eta^2_p = .252$). For the Gender effect, across devices males ($M = 65.5$) progressed significantly further through the course than females ($M = 56.5$). For the significant between-subjects of RacePlay GTF on Progress, the low RacePlay GTF group ($M = 56.1$) made less progress than the other RacePlay GTF groups ($\text{[Medium } M = 66.3, p < .01], \text{[High } M = 65.8, p < .05])$.

For the interaction between Age and Control Device for Progress (shown in Figure 3C), all age groups progressed significantly further with the SpeedWheel (\text{[Youngest } $M = 67.4, \text{Middle } M = 61.6, \text{Oldest } M = 61.8]$) than the RacingWheel (\text{[Youngest } $M = 63.1, p < .01], \text{[Middle } M = 57.3, p < .01], \text{[Oldest } M = 57.2, p < .05])$. For the oldest group Progress differences between other devices were non-significant. Only the two younger groups progressed significantly further with the Controller (\text{[Youngest } $M = 70.6, \text{Middle } M = 64.6]$) than the RacingWheel (\text{[Youngest } $p < .001, \text{Middle } p < .001]$). Within device, the only significant result revealed that for the Controller the youngest group made more Progress than the oldest group ($M = 59.2, p < .01$), with all other differences non-significant.

**Errors**

For the mixed ANOVA results for Errors, Mauchly's Test indicated that the assumption of sphericity had been violated for Errors with Age ($W = .9, \chi^2 (2) = 6.25, p < .05$) and Gender ($W = .88, \chi^2 (2) = 8.06, p < .05$) as between-subject factors, and so adjustments ($\text{AGAE } \epsilon = .91, \text{GENDER } \epsilon = .89$) were used for their within-subjects analyses. Significant interactions were found between Age and Control Device ($F(3.64, 111) = 3.74, p < .01, \eta^2_p = .109$) and Gender and Control Device ($F(1.78, 110.3) = 3.35, p < .05, \eta^2_p = .051$) for Errors. A significant between-subjects effect of RacePlay GTF on Errors ($F(2, 61) = 6.83, p < .01, \eta^2_p = .183$) revealed that the low RacePlay GTF group ($M = 1.45$) made more errors than the other RacePlay GTF groups ($\text{[Medium } M = 0.64, p < .01], \text{[High } M = 0.65, p < .01$). Interaction and between-subjects effects of RaceLife familiarity on Errors were non-significant.

For the interaction between Age and Control Device for Errors (shown in Figure 3D), the difference in Errors between devices was only significant for the oldest group, such that they had significantly more errors with the Controller ($M = 2$) than the SpeedWheel ($M = 0.85, p < .05$) or RacingWheel ($M = 1.05, p < .05$). For the within-device effects, only the Controller yielded a significant difference between Age groups, with the oldest group producing significantly more errors than the youngest group ($M = 0.28, p = .001$). All other between and within-device results for Age were non-significant. For the interaction between Gender and Control Device for Errors, males and females showed no significant difference between devices. However, females did show significantly more Errors than males on both the Controller ($p < .001, \text{FEMALES } M = 2.1, \text{MALES } M = 0.49$) and RacingWheel ($p < .01, \text{FEMALES } M = 1.48, \text{MALES } M = 0.61$). The difference between genders on the SpeedWheel, however, was non-significant.

**Perceived Intuitive Controls (pIC) (PENS)**

For the mixed ANOVA results for perceived Intuitive Controls (pIC) from PENS, Mauchly's Test indicated that the assumption of sphericity had been violated for Gender ($W = .84, \chi^2 (2) = 10.6, p < .01$) and RaceLife familiarity ($W = .83, \chi^2 (2) = 10.9, p < .01$), and so adjustments (both $\epsilon = .86$) were used for their within-subjects analysis. A significant main effect of Control Device on Intuitive Controls ($F(1.73, 106.9) = 4.55, p < .05, \eta^2_p = .068$) was qualified by interactions between Control Device and Gender ($F(1.73, 106.9) = 3.99, p < .05, \eta^2_p = .06$) and

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**Figure 3:** A Range of the Significant Interactions Revealed for device GTF, Progress, Errors and perceived Intuitive Controls
Control Device and RaceLife familiarity ($F(3,43, 104.6) = 2.93, p < .05, \eta^2_p = .088$) for pIC. While interactions for Age and RacePlay GTF were non-significant, a significant between-subjects factor effect across devices was revealed for Age ($F(2, 61) = 3.6, p < .05, \eta^2_p = .105$), yet step-down analysis failed to reveal any significant pairwise comparisons (all $p > .05$).

For the interaction between Gender and Control Device for perceived Intuitive Controls (shown in Figure 3E), the difference between devices was only significant for females, such that the Controller ($M = 4.7$) was reported as significantly less intuitive than the RacingWheel ($M = 5.84$, $p < .01$). The difference in pIC between genders was also significant for the Controller ($p < .05$), such that males ($M = 5.7$) reported the device to have significantly higher pIC than females ($M = 4.7$), yet the differences between genders for pIC were non-significant for the SpeedWheel and RacingWheel. For the interaction between RaceLife familiarity and Control Device for perceived Intuitive Controls (shown in Figure 3F), the difference between devices was only significant for the high RaceLife group, such that the Controller ($M = 4.91$) was perceived to be significantly less intuitive than the RacingWheel ($M = 5.95$, $p < .01$). Differences between and within devices for the other groups were all non-significant.

**DISCUSSION**

**Device GTF percentage and Progress**
While results for device GTF indicate participants’ past familiarity with the control devices tested, Progress reveals their empirical skill level with these devices during the experiment. Overall, however, the device GTF results show similar patterns of results for the Age and RacePlay GTF groups, with a general trend towards higher familiarity with devices with the least natural mapping (Controller and SpeedWheel). All groups showed more familiarity with the SpeedWheel than the RacingWheel, perhaps reflective of the recent pervasiveness of accelerometer-based motion control devices for racing games as compared to the larger, older arcade racing devices. Only the younger age groups and those with more racing game familiarity were more familiar with the Controller than the RacingWheel, suggesting that the oldest and lowest racing game familiarity groups lack experience with traditional controls. The within-device results also reflect this trend, with the older and lowest racing game familiarity groups reporting less familiarity than other groups with the Controller and SpeedWheel. Familiarity differences between these two controllers were only shown in the youngest/higher racing game familiarity groups reporting more familiarity with the Controller than the SpeedWheel, perhaps indicative of the pervasiveness of traditional devices for those that play the most.

Progress results generally reflect previous experience as measured through device GTF, with the same Age groups that had higher familiarity also making more Progress. The only exceptions to this were that the youngest group did not make more Progress with the SpeedWheel than the other groups and also did not make more Progress with the Controller than the middle Age group. All other between and within device GTF differences for Age accurately predict the resulting performance differences as measured by Progress, such that the age groups that had higher familiarity with a specific device also performed better with that device (and vice versa). Males also reported higher device GTF and progressed further than females, further strengthening the relationship between the two measures. These gender differences could be reflective of heavier game play patterns for males in society, or representative of a gender preference for racing games. While the same patterns revealed by the different racing game experience groups in device familiarity were not shown in Progress, those with more racing game experience did make further Progress through the course across devices than the least experienced group. Altogether, the correspondence in results between device GTF and Progress provides evidence of the value of GTF as a measure of previous experience that can reliably predict performance. Since Progress in this study also represented the intuitive interaction measure for ‘time to complete set tasks’, GTF also appears to have been successful for replicating some of the technology familiarity (TF) measure’s ability to predict intuitive use outcomes.

**Perceived Intuitive Controls (pIC) and Errors**
The perceived Intuitive Controls (pIC) measure from PENS and the Errors measure represent a newer subjective and a more traditional objective approach to measuring intuitive interaction. The interactions for Gender and Age for Errors help to explain some of the equivalent interactions for Gender and RaceLife familiarity for pIC. For instance, males showed no difference in Errors or pIC between devices. Females, however, produced more Errors with the Controller than males and also found that device less intuitive (pIC) than males. Likewise, the oldest group had more Errors with the Controller than the other devices and those with the most real-life racing/driving experience reported that the Controller offered lower perceived Intuitive Controls. Age and RaceLife familiarity have a significant positive correlation (Pearson’s $r(64) = .514$, $p < .001$), which is understandable given that older participants have had more time and opportunity to become familiar with racing/driving in real-life. A relative lack of experience with traditional control devices for the oldest and high real-life racing groups could explain their higher Errors and lower perceived Intuitive Controls, however it also might suggest that higher natural mapping in the SpeedWheel and RacingWheel are enabling intuitive interaction to take place. This is further strengthened by Errors and pIC indicating either the same or higher levels of intuitive use for the more naturally mapped devices for all between-subject factor groups (except for female errors.
with the RacingWheel) despite most groups having less device familiarity with the SpeedWheel and RacingWheel. That more naturally mapped devices produced a higher level of pIC only for those with the most real-life racing/driving experience also emphasises the importance of accurately measuring familiarity with real-life equivalent interfaces when measuring intuitive use outcomes in games. However, lack of differences for device GTF, Progress and Errors for the RaceLife familiarity groups indicates that real-life racing/driving experience does not automatically lead to higher racing game familiarity or performance.

Not all results were reflected cleanly between perceived Intuitive Controls and Errors, strengthening the argument for a multi-modal (subjective and objective) approach to measuring intuitive interaction in games. For instance, the oldest group produced significantly more Errors with the Controller than the youngest group, yet there were no differences between any of the real-life racing/driving familiarity groups regarding the perceived intuitiveness (pIC) of any device. Additionally, while females produced more Errors with the RacingWheel than males there was no difference in pIC between genders for this device, yet females did report that the RacingWheel was more intuitive (pIC) than the Controller. That is, although females produced more Errors on the RacingWheel and Controller than males, and both genders showed no difference in Errors between devices, females still indicated that the more naturally mapped devices were more intuitive (pIC) than the Controller. Combined with the other between-subject results for females and those with the least racing game experience (less device Familiarity, lower Progress and more Errors), this may lend support to the argument for naturally mapped controls as a means to provide accessibility through increased potential for intuitive interaction. The contradictions between device familiarity and the intuitive use outcomes for different age groups may add further weight to this argument. For instance, most age groups reported less familiarity with each of the more naturally mapped devices, yet the only difference between devices for Errors was that the oldest group produced more errors with the Controller. Once again, it appears that familiarity as measured through GTF may provide a good indicator of intuitive use outcomes, yet natural mapping (or transferring knowledge across domains) might compensate for lack of previous experience, especially for those with less experience in the domain.

**Natural Mapping and the Intuitive Interaction Continua**
Tying these results back to the continua for intuitive interaction shown in Figure 1, stronger natural mapping takes advantage of lower (more base and pervasive) levels of knowledge (sensorimotor/physical affordance), whereas devices that employ weaker natural mapping rely more on specialised knowledge (such as Culture / Population Stereotypes and Expertise/Knowledge from same domain). The difficulty of naturally mapping an activity depends on both the pervasiveness of the knowledge being leveraged, which in turn depends on the frequency of encoding/retrieval for the mapped activity, and how directly the actions to be mapped can be transferred. Put another way, it depends on both the cultural penetration of the activity and the level of metaphor required to naturally map its action to an available interface. This may explain why certain activities are more frequently simulated in videogames using Naturally Mapped Control Interfaces (NMCIs). For instance, driving as a skill has a high level of cultural penetration not only because a majority of adults learn it but also since children are encouraged to participate in activities using similar skills from an early age (riding on trikes, go-karts, etc.). Thus the conceptual model for the activity has a high level of penetration in society, and the basic control actions for this activity also easily map to accessible and pervasive tilt-based and mechanical control input technologies. NMCIs types for videogames that use a high level of natural mapping for such activities can hope to encourage a higher potential for intuitive use. However, this potential is only greater than the potential for intuitive interaction leveraged through expertise knowledge (e.g. by traditional control inputs with lower natural mapping levels) when targeting those either with low game device familiarity or high relevant real-life experience. Users with a high level of experiential knowledge using traditional interfaces in the same domain/genre (or able to transfer these skills from a similar domain/genre) will be primed for intuitive use with traditional interfaces leveraging their expert knowledge of tools. Since "...intuitive use is most beneficial for first, early and intermittent use of interfaces" [6], the accessibility benefit or intuitive potential of NMCIs may only be applicable to casual or intermittent gamers (those with low same domain familiarity) or those approaching the genre for the first time. This possibility needs to be explored further, along with the question of whether there are additional factors, such as broader play experience outcomes, related to the use of control interfaces for videogames that might influence the design of interfaces with the potential for intuitive interaction in this space.

**SUMMARY AND FUTURE WORK**
Different types of naturally mapped control interfaces in a racing game, classified using Skalski et al.’s typology [21], produced distinctly different intuitive use outcomes between devices. The lack of an experiment-wise Bonferroni correction in the current study resulted in a elevated chance of Type I errors and future work should aim to confirm these findings with a larger sample and more conservative statistical analysis. While more naturally mapped devices may offer a higher degree of control more closely equivalent to the real-life activity, they also provide greater potential for intuitive use for those with less gaming experience and/or higher familiarity with the real-life activity. While this increased potential for intuitive use may be limited for high familiarity gamers, due to their overwhelming familiarity with traditional interfaces, this
does not automatically make naturally mapped controls detrimental for this group. It does, however, allow for first time or occasional gamers to leverage experiential knowledge to make gaming more accessible. Further definition of these player familiarity types and of naturally mapped control device types, as well as broader exploration of related play experience outcomes, will form the focus of our future work.

This paper presented a new approach to measuring previous gaming experience. Evolved from similar measures to help predict intuitive interaction [6]. Game Technology Familiarity (GTF) provides a deep and reliable previous experience measure that can be adapted for unique combinations of control interfaces and game types. Drawing on intuitive interaction theory, GTF also emphasises the importance of measuring familiarity with similar devices and activities, given that these form an amalgamated pool of experience referenced for intuitive use that may also influence other play experience outcomes. Measurement of accuracy and time to complete tasks as employed in intuitive interaction research was also adapted for games research using Errors and Progress. Future work should test implementation of these measures, and their potential to predict and explicate intuitive use, against traditional measures of previous play experience and across different videogame genres. While research in genres with a clear potential for naturally mapped controls is needed, such as in sports and actions games, future work should also seek to explore motion controls where the in-game activity is not so clearly mapped to the real world.

REFERENCES