Intuitive Interaction with Motion Controls in a Tennis Video Game

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ABSTRACT
This paper broadens understanding of intuitive use in games by testing the influence of three naturally mapped motion control interfaces in the context of a tennis video game. It also extends exploratory work on natural mapping and intuitive interaction in video games by refining instruments to measure game technology familiarity. Repeated-measures experiment data (N = 120) is analysed via mixed ANOVAs with four distinct player characteristic variables. As with broader intuitive interaction research, results show that more familiar players performed more effectively; however, where differences exist, they point towards increased intuitive use gains with more naturally mapped control interfaces. Subjective measures suggest that control interfaces were perceived as more intuitive when they had higher levels of natural mapping, yet also point to the influencing roles of familiarity and the dimensions of the control types in shaping these perceptions.

CCS CONCEPTS
• Applied computing~Computer Games; • Human-centred Computing~Gestural Input

KEYWORDS
Video Games; Tangible and Embodied Interaction; Natural Mapping; Intuitive Interaction; Games User Research

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1 INTRODUCTION
As video games have matured, one of the key drivers of change and growth for both the medium and the industry has been innovation in the design of control interfaces [63, 69]. From the introduction of the analogue thumbstick to the mass popularity of motion-controlled gaming with the Nintendo Wii, this innovation has often been tied to an increase in the level of natural mapping between the control interface and the game. Naturally mapped control interfaces for video games draw on physical and cultural analogies to increase the level of correspondence between the physical control interface and the virtual effects in the game world to which the control inputs are mapped [63]. What started with directional correspondence in the earliest control interfaces progressed to tracking the player’s movement of their body in 3D space and mapping this to the virtual world. Game developers have also attempted to increase natural mapping in the control interface in other ways, such as by making the look and feel of the control interface more like the equivalent real-life interface that the game is attempting to simulate (e.g., fishing rod peripherals, tennis racket attachments for motion controllers, etc.). Other technologies have also facilitated different, sometimes complementary, approaches to integrating higher levels of natural mapping in video games, including the use of touch, voice, haptic feedback, cameras and virtual reality displays. As a whole, naturally mapped control interfaces are claimed to offer more intuitive and transformative experiences for players compared with traditional control interfaces [31, 32, 64], yet the extent to which these claims have been tested remains limited.

Industry claims regarding the supposed ‘intuitiveness’ of natural control interfaces have been broadly echoed in the games research community [15, 44, 47, 68, 70], where intuitive controls have been identified as a key factor contributing to the player experience of need satisfaction (PENS) [57]. Researchers in the field of intuitive interaction, meanwhile, formally defined intuitive use as subconsciously drawing on experiential knowledge, and devised tools to measure relevant previous experience levels and objectively assess intuitive interaction [8, 36, 48]. Researchers also identified a connection between natural mapping and intuitive interaction [9, 37], with preliminary work suggesting that the potential for intuitive use might increase with interfaces that employ higher natural mapping [5, 23, 42, 46].

Despite claims of the intuitive value of natural controls, overt intuitive interaction research on video games has been sparse [43, 44, 46]. Further, tools to measure relevant familiarity and intuitive
use have been designed yet require further adaptation and validation [44]. This paper refines an existing approach to measuring familiarity and intuitive interaction outcomes and operationalises these for a study evaluating three types of motion control interfaces for a tennis video game. Results clarify the relative influences of different control interface types and relevant familiarity on perceived and objective measures of intuitive interaction with the game. While intuitive interaction outcomes tend to follow control interface familiarity, increased natural mapping can also facilitate these outcomes in the absence of relevant familiarity. These results also highlight how the dimensions of naturally mapped control interfaces (their realism, bandwidth and naturalness), along with certain player characteristics, can also influence responses.

2 LITERATURE REVIEW

2.1 Naturally Mapped Control Interfaces

As motion-controlled gaming rose in popularity, researchers set out to assess the influence emerging control interfaces had on the experience of video game play [1, 45, 47, 61]. Naturally Mapped Control Interfaces (NMCIs) were first broadly categorised as either natural or non-natural, yet as work continued, a richer picture of the relevant control interface types emerged. A typology for NMCIs was proposed that identified four initial types and ranked them in terms of their position on the natural mapping continuum [63]. From least to most naturally mapped these types were directional, kinesic, incomplete tangible and realistic tangible. Directional natural mapping takes place when there is simple ‘correspondence’ in direction between physical control inputs and virtual control actions, such as pressing a control stick up to make a character move forward or jump. Kinesic natural mapping occurs when natural body movements are captured and translated into equivalent actions in the game space without a tangible component (e.g. crouching to make the character duck or dancing to match movements in a dance game). Incomplete tangible natural mapping is when the player is provided with a physical object to manipulate that ‘partially simulates’ the feel of the equivalent virtual object, such as swinging a Wiimote like the hilt of a sword for a fighting game. Realistic tangible natural mapping happens when the control interface both looks and feels the way the corresponding in-game object would in the real world, such as a realistic arcade gun that maps aiming movements into the game and provides haptic effects like recoil.

Preliminary work validating some of these NIMCI types found that higher natural mapping in the control interface could have a positive influence over certain aspects of the video game player experience [21, 56, 62, 63]. However, not all research produced consistent results [15, 41, 56, 67] making the position of certain NIMCI types on the natural mapping continuum uncertain. Research has also suggested that the type of control interface can influence the manner in which games are cognitively processed. Where a physical device is used to control the game, the extent to which the control interface is perceived as realistic directly influences enjoyment, however, where no device is used (the game is controlled using only the body), perceived realism is less important for enjoyment [53]. Relatedly, Kim et al. [38] found that greater user interface embodiment in an exergame influenced presence, enjoyment, energy expenditure and intention to engage, and there is evidence to support that movement recognition precision can lead to greater levels of immersion [49]. Similarly, Vara et al. [68] found evidence for improved outcomes in a serious game designed to improve emotion regulation when more natural and physically demanding control methods were used.

More recently, work has questioned the broad nature of the NIMCI control types and proposed a refined approach to their classification based on the more specific dimensions that underlie the typology [43, 54]. These include realism (or the physical characteristics of the controller), bandwidth (or the accuracy and fidelity of the controls supported by the underlying technologies) and naturalness (or the correspondence between physical and virtual control actions and the equivalent real-life activity that inspired the control interface metaphor) [43].

2.2 Familiarity and Intuitive Interaction

Intuitive interaction research established the definition of intuitive use as when people draw on subconscious experiential knowledge for quick and effective interaction with products and interfaces. Researchers have presented a continuum of knowledge for intuitive interaction, which offers insight into how to design for and measure intuitive use [10–12]. Since intuition is dependent upon experiential knowledge, a technology familiarity (TF) questionnaire also emerged from this work to measure relevant exposure, which has been shown to predict intuitive use across a range of domains. Objective empirical measures for coding participants’ intuitive uses with an interface were also established, including coding for the intuitiveness of each interaction as well as correctness of the interaction in relation to the sub-task [13, 25]. Defining and analysing intuitiveness has been enabled by the use of talk-aloud protocols with participants and other objective data sources such as coding video of participants completing tasks for accurate uses and errors. Accuracy or error count is a relevant measure as intuition is generally acknowledged to be fairly effective in providing solutions.

Time on task is also relevant to quantifying intuitive interaction as intuitive processing is assumed to be faster than more conscious types of processing [3, 6, 59], so participants interacting intuitively with a product should be able to complete tasks more quickly. Thus, many researchers in intuitive interaction have used time or clicks to complete tasks or subtasks, latency and correctness of uses, error counts or successful task completion in order to help identify intuitive interaction [18, 44, 52, 53]. Some researchers have also applied established measures and data collection procedures from psychology, such as dual task protocols, in order to understand more about how intuition powers intuitive interaction and to find ways to apply it to and test interfaces more easily and efficiently [28, 29, 65].

Ongoing intuitive interaction research has expanded the field by building on the established theory and measurement tools through their application in a range of domains. Two of the themes this work has focused on includes the relationship between aging, familiarity and intuitive use [14, 46, 50, 51] and the relationship between ‘natural user interfaces’ and intuitive interaction [5, 23, 42, 46].
Subsequent designs of the TF questionnaire have been adapted to fit the study domain, adjusting the interface and product knowledge sampled to be relevant to the research context. Overall, intuitive interaction research suggests that through considered design, natural user interfaces can increase the potential for intuitive use. However, more work is needed. Unique design challenges, such as applying the correct mapping metaphor, making interactions discoverable, and considering ergonomic factors, must also be overcome [14, 34, 46, 50, 51].

2.3 Intuitive Use in Video Games

Since technology familiarity emerged as the most reliable predictor of intuitive use in intuitive interaction research, we developed a similar measure in our previous work to sample relevant previous technology interactions to evaluate intuitive interaction with video games [43, 44]. First designed to sample previous experiences relevant to interaction with racing games, the game technology familiarity (GTF) instrument measured exposure to the actual control interfaces tested as well as similar control interfaces and interface features. These design elements, along with administering the instrument as a guided questionnaire to ensure both consistent implementation and participant comprehension of the game-specific technology items, were in line with the original TF measure [8]. However, in adapting the measure for application in the games research domain, several changes were introduced in the GTF instrument design as well as the scoring and analysis protocol applied to its responses and the objective measures of intuitive use, to make them better suited for use in this field [43, 44]. For example, a ‘correct’ or ‘on-task’ action in games is not always identifiable or relevant and talk-aloud protocols may have undesirable impacts on the player experience.

Changes to GTF sought to make the instrument better reflect the variation in relevant previous gaming and real-life experiences between participants [43, 44]. Its initial implementation evaluated familiarity relevant to the use of naturally mapped control interfaces in a racing game study and found it to be a reliable predictor of intuitive use outcomes (measured as percentage of the race complete and the number of coded errors). This was demonstrated by using relevant control interface familiarity (GTF) as a between-subjects measure, as well as examining differences revealed by other player characteristics such as age and gender. Where discrepancies between GTF and intuitive use occurred, they appeared to indicate that higher natural mapping in the NMCIIs offered some compensatory effects for reduced familiarity and were not detrimental to more experienced players.

With the exception of the work of outlined above [43, 44], previous games research has not sought to explicitly measure intuitive use. However, general performance measures offer some insight into the intuitive potential of naturally mapped control interfaces, even though measurement of familiarity (or some form of previous gaming experience) to cross-reference the source of intuition is inconsistent and/or lacking [9, 12]. With that qualification in mind, research has generally shown that players perform better with less naturally mapped control interfaces [2, 33, 41, 45, 56]. However, there are a few notable exceptions to these findings [4, 20, 26, 44]. Andersen et al. [4] showed higher performance with the Kinect controlled version of their self-developed obstacle course game, yet the way the game was developed might have favoured this condition over the version controlled using a traditional controller. Brown et al. [20] showed that performance was higher with a racing wheel controller than with traditional control inputs, yet this sample was limited (only 12 participants). Other research has consistently shown performance to be higher with traditional controllers in racing games compared with steering wheel controls (as also broadly shown in [44]). Downs and Oliver [26] showed that motion controls support better performance than button-based controls in a golf game.

The majority of NMCI games research that has measured some form of previous experience and performance appears not to have examined the relationship between the two, although the few that report analysing it appear to have found no effects [2, 33, 41, 54, 58]. The two exceptions are [4], which found that gamers performed better than non-gamers, yet only for the controller condition, and [19], which found that players performed better on interfaces for which they reported higher previous experience, higher skill or previous game exposure. Of all the games research examining NMCIIs in relation to performance, only [33] and [54] report testing for the influence of age and found no result, although the maximum ages in their samples were 30 and 27 years respectively. Comparatively, in our previous work [44], age was shown to affect familiarity and both objective intuitive use measures, highlighting patterns that revealed the compensatory effect of NMCIIs. Exploration of the effects of gender in NMCI research is similarly limited. One racing game study showed that males generally performed better than females for the traditional (less natural) control interface [2], which was supported by similar results in [44]. Some research has shown a between-subjects effect of gender on performance, with males performing better than females across control devices [19, 41]; however, effects of both gender and age might also be generally attributable to the influence of previous gaming experience or relevant control interface familiarity [43, 44].

More work is needed to validate these results across varied gameplay contexts with strict protocol to more effectively operationalise performance measures as representative of intuitive use.

2.4 Perceptions of Intuitive Use in Games

Ryan et al. recognised that how intuitive the player perceives the controls to be is a major factor contributing to the degree that psychological needs are satisfied during play [57]. Birk and Mandryk’s study [7], which tested three control interfaces in a custom-developed shooter game, represents one of only three NMCI studies that has measured perceptions of intuitive controls using the PENS instrument. Other research has sampled ‘sense of control’ measures with NMCIIs that have generally supported stronger results for traditional control interfaces, yet the wording of items does not explicitly tie the measure to the player’s sense of intuitive use [2, 33, 41]. Birk and Mandryk [7] showed that a tangible control interface (Move) led to higher perceptions of intuitive controls, yet participants in their study also rated a Controller as more intuitive than Kinect. However, the control interface mapping of Kinect in [7] utilised a different metaphor and
mapping scheme from the other devices tested, which might limit the generalisability of their findings for the kinesic NMCI type. Nevertheless, the research does show that an incomplete tangible NMCI (Move) was perceived to have more intuitive controls than a directional NMCI (Controller) in another gaming context. Our previous work failed to show this difference as significant [44], with only the realistic tangible NMCI (the RacingWheel) significantly higher than the Controller. However, this work did reveal an interaction effect between real-life familiarity and the control interface for intuitive controls, which suggested that only those most experienced with racing and driving in real life perceived the most natural NMCI as more intuitive. This work thus served to highlight the need to track exposure to equivalent real-life activities for naturally mapped interfaces, even though this type of familiarity only influenced perceptions, and not objective measures, of intuitive use.

More recent work also revealed an influence on perceived intuitive controls, with results for this measure lower for a control interface classified as incomplete tangible compared to those classed as kinesic and realistic tangible in a tennis game after controlling for the effects of gender [54]. However, the more natural NMCI types in [54] were physical props that were not tracked by the Kinect control interface used in all conditions. Specifically, the interface classified as incomplete-tangible natural mapping was a sawn-off tennis racket handle, which the authors admit "looks like a damaged tennis racket", and since it served no technical purpose in the control interface these factors may have worked to negatively influence participants’ related perceptions. Not all work heralds the perceived intuitive benefits of more natural controls, with many players preferring traditional control interfaces for certain gaming contexts. Research on player experiences with natural user interfaces has found that players often highlighted their relative lack of precision as well as their potential for lowered success in the game [16, 40].

In all, existing work has generally supported the idea that higher natural mapping in the control interface can lead to increased intuitive interaction outcomes and perceptions of intuitive use. However, NMCI research remains limited both in its empirical evaluation of intuitive use and validation of all the naturally mapped control interface types across a range of gaming contexts.

3 METHOD
This study presents previously unpublished work from a larger research programme designed to explicate the influence of naturally mapped control interfaces (NMCI) for video games on the player experience and intuitive interaction (see [43] for further details). The work presented here relates to the second study in this programme of research. The guiding research questions were:

1. How does the use of different naturally mapped control interface types affect intuitive interaction with video games?
   and

2. How do these effects vary according to player characteristics?

Following ethical approval, one hundred and twenty-five participants (37 females and 83 males), age ranged from 17 to 62, with a mean age of 28.1 years (SD = 9.62). Participants were recruited through a mix of online social networking, personal and professional networking (in person and via email) and announcements in undergraduate interaction design and computer games studies units. The chance to win a $100 gift card was offered as a recruitment incentive to the participants.

3.1 Stimulus and Manipulation
The ‘Motion Play’ game mode in Virtua Tennis 4 [60], a tennis video game for Xbox 360 and PlayStation 3, was chosen as the main stimulus for the study. This choice reflected our desire to answer the research questions in the context of a commercial video game that was consistent across control interface types to increase ecological validity and avoid some of the additional confounding factors in similar work [4, 7, 15, 41, 54, 56, 67]. The stadium (Melbourne, Australia), characters (Federer for the participant and Djokovic for the AI-controlled opponent), game rules (six games, one set) and AI difficulty (easy) remained consistent for all study conditions. These settings were selected following pilot study sessions to provide a consistent and familiar tennis gameplay environment that equally supported novice and more experienced players. The game was set up so that Federer (the player) always served for the first game to give participants control over initiating points when they were becoming accustomed to the controls. Participants were asked to avoid pressing any buttons during play, as only motions were required for all of the control actions. The main control actions in the game are hitting the ball, moving the racket, serving, and moving on the court. Moving the racket (including positioning it in relation to the body) and hitting the ball are the core game mechanics that require the most frequent interactions. Serving the ball occurs only at the start of a game point when it is the player character’s turn to serve. Moving on the court is a limited and optional game mechanic, whereby players can approach or move back from the net. The virtual characters automatically move left and right on the court to return the ball, so the player’s physical movements in these directions are not mapped, yet swinging the arm on the correct side of the body is required to hit the ball.

The ‘Control Interface’, the main independent variable, was operationalised with three interfaces, each determined to clearly represent a distinct type from Skalski et al.’s typology of NMCI types [63], as shown in Figure 1 on the continuum of natural mapping (from the least to most naturally mapped). Kinect, a motion control peripheral released by Microsoft for the Xbox 360 in November, 2010, was classified as a kinesic NMCI since the player uses only their body movements to input control actions without the use of a tangible controller (e.g. swinging their dominant hand across the front of their body to make Federer perform a backhand hit). In this study, players moved their arm and hand around in 3D space to move their virtual racket, as well as hit and serve the ball, and moved their body away from or towards the screen to move back and forth from the net. Although the speed and 3D position of the hand and arm (in relation to the body) are tracked by Kinect and translated into the way the ball is struck, precise orientation and movements of the hand and wrist are not tracked.
ball, yet theoretical or embodied knowledge of this technique might be required to perform it well. For example, players can theoretically allowing for a finer degree of control over the way the character strikes the ball than with Kinect. For example, players can manipulate an on-screen cursor) compared to the Move/RSM differences and required different instructions for Kinect (manipulating an on-screen cursor) compared to the Move/RSM (simply pressing the start button on the side of the device). There were no other discernible differences between the experiment conditions except for the NMCI differences identified above, and the minor graphical differences were peripheral to or outside gameplay.

3.2 Procedure

The experiment was conducted with participants individually and each session took around one hour to complete. Participants were asked to indicate their gender and age while scheduling their study session, which was controlled for when determining the random counterbalanced order of the control interface conditions they encountered in the experiment. The participant’s dominant tennis hand was also captured during this process to facilitate control interface setup. Upon arriving at the laboratory, participants were given a brief scripted verbal overview of how the study session was to be conducted. Following this, the researcher administered the player characteristics and Game Technology Familiarity questionnaires as a guided online survey on a PC (refer to supplementary materials). This section of the study concluded with participants filling in additional demographic details, and took between 5–15 minutes in total. The following procedure was then initiated to have the participants play Virtua Tennis 4 [60] with their first assigned control interface in the laboratory’s play space (see Figure 2).

![Figure 1: NMCI Classification of the Control Interfaces](image1)

The PlayStation Move (a motion control peripheral released by Sony for the PlayStation 3 in September, 2010; from this point referred to as ‘Move’) was classified as incomplete tangible natural mapping, since players manipulate the device like the real-life equivalent tool, but it does not realistically mimic the look or feel of a tennis racket. In this study, players moved the Move around in 3D space to move and position their racket, as well as hit and serve the ball, and moved the Move towards and away from the screen to move back and forth from the net. While the Move only tracks movement of the player’s dominant hand holding the device, it does so by also sampling rotation and orientation data in addition to 3D positional data. Kinect and Move also feature different sampling frequencies (Kinect: 30 Hz; Move: 87 Hz) and mean latencies (Kinect: 142 ms; Move: 68 ms) [54]. This means players can move their virtual racket with almost a one-to-one level of mapping fidelity from the Move’s physical position and orientation, theoretically allowing for a finer degree of control over the way the character strikes the ball than with Kinect. For example, players can rotate their hand up and over a forehand hit to add topspin to the ball, yet theoretical or embodied knowledge of this technique might be required to perform it well.

The Racket Shell Move (RSM) is a primarily plastic, racket-shaped mould that the PlayStation Move can clip into, which was released with the tested game in a retail bundle. It was classified as realistic tangible natural mapping because it is not only manipulated like a tennis racket, but also mimics the look and feel of the equivalent real-life tool. Control actions are captured and tracked exactly the same as with the Move interface; the only difference is that the RSM more fully completes the player’s mental model of a tennis racket through its physical properties. Finally, a vibration motor present in the Move controller, which rumbled to indicate contact with the ball, remained in its default setting for the Move and RSM conditions. These and the other differences identified above were determined to be congruent with the original definitions of the corresponding NMCI types [63]. Both consoles were set to the same resolution of visual output (720p) and displayed on the same 55-inch screen, with graphical differences between the two consoles limited to minor interface elements. For example, the menu from which participants commenced play had minor differences and required different instructions for Kinect (manipulating an on-screen cursor) compared to the Move/RSM (simply pressing the start button on the side of the device). There were no other discernible differences between the experiment conditions except for the NMCI differences identified above, and the minor graphical differences were peripheral to or outside gameplay.

![Figure 2: Configuration of the Test Environment](image2)
Interfaces. Participants were instructed to remain within the play space during play to stay within the range of the sensors.

Once each participant confirmed that they understood the procedure, they were prompted to un-pause the game as they stood ready on the starting mark in the test environment. During the play session, the researcher remained in the ‘observation chair’, out of the player’s sight, to observe player behaviour, capture observational notes and facilitate the experiment. After six minutes of play time, the screen was remotely deactivated and participants were asked to return to the survey PC to complete an online player experience survey (on their own) based on their time playing the game with the assigned control interface (refer to [43]). This survey took approximately 5-15 minutes to complete, concluding with open-ended questions that captured participants’ positive and negative impressions of the control interface. Participants were then asked to play the game again with the next assigned control interface and the above process was repeated for the second and third conditions. After the third player experience survey regarding the final control interface, some additional survey questions sampled overall NMCI preferences and general feedback before the study session concluded. Although analysis of the observational notes and open-ended questions is beyond the scope of this publication, the former were useful in supporting the removal of outliers for statistical analyses.

3.3 Measures

Age, Gender, Game Technology Familiarity (GTF) and TennisLife familiarity are included as player characteristic factors, along with the dependent variables Successful Hit % and Intuitive Controls. An overview of how these measures were captured in the context of the experiment procedure is show in Figure 3.

![Figure 3: Measures in the Context of Experiment Procedure](image)

Altogether, intuitive interaction was measured in three ways: its potential to occur based on familiarity (GTF), objective empirical markers for its occurrence (Successful Hit %), and subjective self-reported levels of its perceived occurrence (via Intuitive Controls from PENS). Refer to [43] for the details and results of the larger set of player experience measures that were sampled for this study, including competence, presence, autonomy, flow, perceived naturalness, enjoyment/satisfaction, and player preferences for control interfaces.

3.3.1 Demographics and Subjective Response.

Age and Gender were sampled as player characteristic factors in the survey administered prior to play and grouped as between-subject factors for analysis. Non-binary gender options were offered but not selected by any participants. Following each condition, the player experience was sampled using an 18-item version of the PENS, which measures in-game satisfaction of psychological needs [57]. The PENS implementation asked participants to think about their time playing the game with the control interface just used and rate their agreement to the items on a seven-point Likert scale between ‘1—do not agree’ and ‘7—strongly agree’. Intuitive Controls consists of three items and is high when the controls make sense and do not interfere with game involvement (example item: “When I wanted to do something in the game it was easy to remember the corresponding control”). Item order for the PENS was randomised upon presentation to participants, and the score for each of the components calculated as the average of its items.

3.3.2 GTF and TennisLife Familiarity

Four familiarity scores were calculated for each participant using the game technology familiarity (GTF) approach to sample relevant familiarity as a predictor of intuitive use [44]. Three GTF scores related to their familiarity with each of the NMCI types tested (‘kinesic GTF’, relating to Kinect familiarity, ‘Incomplete Tangible GTF’, relating to Move familiarity, and ‘Realistic Tangible GTF’, relating to RSM familiarity), while ‘TennisLife Familiarity’ encapsulated participants’ relevant previous real-world experience (i.e. playing tennis or similar games/sports in real life). The items of the GTF instrument were thus customised to the domain of the game being studied, to sample use with the actual control interfaces (e.g. Move) and equivalent real-life activity (i.e. tennis), and similar control interfaces (e.g. wand-based motion controllers like the Wiimote) and activities (e.g. table tennis). Two main revisions to GTF were also made to the original implementation [44], to further support participant recall and comprehension as well as increase the accuracy and variability of the scores the instrument produced. The first is that an additional exposure variable – average session duration – was sampled. The main motivation for this change was that duration of play is regarded as an aspect of exposure to video games that can vary greatly between participants. While recent research shows that Australian gamers spend on average 81 minutes per day playing video games, this average value can vary greatly when broken down by player characteristic groups from around 20 minutes to over two hours [17]. This decision was also supported by the identification of duration (labelled ‘intensity’) as a key exposure variable relevant to prior experience by intuitive interaction researchers, along with exposure length and frequency [35]. The form of this question was simply, “When using <the item>, how long was an average session?”, with answer fields supporting any combination of hours and minutes to generate a continuous response variable.

This indicates the second major change in the new version of the GTF: the capture of continuous variables rather than predefined categorical responses [9, 44]. This revision allowed participants to respond with open values in the most common time formats potentially conceivable for the question type. For example, in
sampling the first or most recent time an item was used, participants could respond with a temporal value in years, months, weeks or days, or any combination of these values. Frequency was also revised to sample average frequency (compared to peak frequency in the first version [44]), and allowed participants to respond with a time value (e.g. every six months) or the total number of times the item was used. To maintain instrument validity and make the required changes to GTF iterative, rather than a complete overhaul of approach, the decision was made to integrate the changes within the existing GTF scoring protocol [44]. On a practical level, this meant that the existing formula and scoring system acted as the scaffold within which the new exposure type (duration) and the continuous response variables were integrated. Namely, the same formula and range of scores for $T_i$ (the initial time used), $T_k$ (the most recent time used) and $F$ (average frequency of use) were maintained, with the continuous responses linearly applied within the existing score brackets. The average session duration score ($D$) was combined with $F$, maintaining the same maximum value and weight in the GTF formula, yet relabelled as ‘intensity’. Thus, for each relevant item that was sampled, the following GTF formula was applied:

$$GTF \text{ item score} = \left( \frac{T_i + 1}{2} \right) - \frac{T_k}{T_k} * \left( \frac{2}{T_k} \right) * \left( \frac{F + D}{2} \right)$$

GTF item scores were weighted according to their relevance to the overall familiarity score to which they contributed, as with previous work [22, 44]. The consistency in formula and scoring ensured that once again, no familiarity was equal to a score of zero, and the highest theoretical familiarity score was 25 (though this was only achievable for TennisLife familiarity, with the NMCI GTF scores limited by the commercial availability of related technology). The three GTF scores relating to each NMCI condition were used as a repeated-measures dependent variable (called ‘NMCI GTF Score’) and summed together into a single grouped between-subject factor (called ‘Combined NMCI GTF’) to analyse the other measures. The three GTF scores relating to each NMCI condition were used as a repeated-measures dependent variable (called ‘NMCI GTF Score’) and summed together into a single grouped between-subject factor (called ‘Combined NMCI GTF’) to analyse the other measures. The final scores for TennisLife Familiarity were also grouped into three levels to convert this variable into a between-subject factor. With the revisions to GTF, the formula and instrument arguably better operationalises the diversity of use/exposure that was captured in the original TF instrument, as well as accounting for a broader definition of exposure [9, 35]. The full GTF questionnaire and scoring protocol are included in the supplementary materials.

### 3.3.3 Intuitive Use (Successful Hit %)

Successful Hit % was calculated to operationalise and objectively measure intuitive interaction with the studied game, adapting traditional intuitive use measures such as time to complete set tasks, codified intuitive uses and accuracy [13]. Exactly replicating traditional approaches to intuitive interaction measurement is difficult in games research, since successful interaction with video games is less prescribed than with the utilitarian systems typically examined by researchers. All racket swings by the player, as observed in the captured gameplay footage, were coded using The Observer XT (Noldus, 2011) as either successful or unsuccessful. A successful hit required accurate timing, orientation and swing force to ensure the virtual racket made contact with the ball with enough force for it to travel over the net. Since it was not possible to hit the ball outside the tennis court’s boundary, unsuccessful hits were all hits where the player either missed the ball completely, or the ball bounced off their racket but there was not enough force in the swing for the ball to travel over the net. Serves were not included in the hit count, as these required no accuracy or force for the player to be successful (i.e. it is not possible for the player to produce a ‘fault’—a serve that hits the net or lands outside the correct area of the court—since a successful serve animation is always triggered with variation according to the timing and level of force input through the serving motion). The number of successful hits was converted into a percentage of the total number of hit opportunities for this analysis. The resulting measure arguably captured both ‘correct intuitive uses’ and ‘errors’, since both the number of correct uses (successful hits) and the number of errors (unsuccessful hits) were required to determine the overall percentage. It thus generalised intuitive use for each condition into numerical scores for each participant, which reflected the participant’s ability to correctly and accurately use the assigned control interface to progress towards achieving the given in-game goal in the allotted time. This summative approach replicated previous approaches to measuring intuitive use in that it is generalised in variables that are meaningful encapsulations of unconscious knowledge transfer (i.e. increased effectiveness and mental efficiency) when interpreted through the lens of relevant familiarity [10, 12].

### 4 RESULTS

A series of mixed multi-factorial (two-way) ANOVAs were conducted on NMCI GTF Score, Successful Hit % and perceived Intuitive Controls using the ‘Control Interface’ (Kinect, Move and RSM) as the within-subjects factor. The between-subject factors used were Gender in two groups; as well as Age, Combined NMCI GTF and TennisLife Familiarity in three groups. All grouped between-subject factors were created by splitting participants into three equal-sized groups based on their value for the relevant variable. Where equal-sized groups were not possible (in this case, only for Age) participants were allocated on the basis of forming the closest to equal group sizes possible from the given dataset. NMCI GTF Score was assessed using only Age and Gender as between-subject factors, since it was not entirely independent from the other familiarity factors. Wilks’ Lambda and a more conservative alpha level of $p < .025$ was used as the significance test for the univariate ANOVA results. Additional results with an alpha level of $p < .05$ are also reported where the effect size, as measured by partial eta-squared, is medium or higher according to Cohen’s rule of thumb (i.e., $\eta^2 \geq .06$) [24]. A Bonferroni adjustment with an alpha level of $p < .05$ was applied for all post-hoc pairwise comparisons. Only the differences that satisfy these significance requirements are reported in results.

The data for one participant were removed since the facilitator was ill and needed to conclude the experiment with data collection incomplete. No other missing values required intervention, as missing data was below the accepted threshold [66]. Four participants from the oldest Age group were identified as extreme outliers by examining boxplots. Further investigation of observational notes revealed that for these cases, the participants’ comprehension of the control interface instructions or their commitment to the experiment was unclear. These participants
were also found to cause violations to assumptions of normality across a range of variables. For these reasons, the four outliers were also removed from further analysis, reducing the overall sample size to 120. Additional minor violations to the assumption of normality were accepted, since ANOVA is robust to violations of normality, and in all instances there are both more cases than dependent variables and more than 20 cases per cell [66]. Some caution should be applied interpreting the between-subject factor effects of Age and Combined NMCI GTF on Successful Hit % due to violations to the assumption of homogeneity of variance (as measured by Levene’s test of Equality of Error Variances), yet since group sizes are nearly equal for Age and equal for Combined NMCI GTF, the mixed ANOVAs should be robust to these violations [39, 66]. Violations to the assumption of sphericity are highlighted within each relevant dependent variable, and in all cases were corrected with Greenhouse-Geisser adjustments.

Descriptive statistics for the main independent variable and dependent variables are shown in Table 1, while descriptive statistics for the between-subject factors and their groups, as well the full mean and standard error results, are detailed in the supplementary materials.

### Table 1: Descriptive Statistics for the Main IV and DVs

|                | Kinect | Move | RSM |
|----------------|--------|------|-----|
| NMCI GTF Score | 1.16   | 0.12 | 2.64 | 0.18 | 1.83 | 0.13 |
| Successful Hit % | 78.8  | 0.8  | 85.3 | 0.72 | 90.2 | 0.53 |
| Intuitive Controls | 4.92 | 0.12 | 5.52 | 0.1  | 5.81 | 0.09 |

#### 4.1 NMCI GTF Score

The mixed ANOVA for the NMCI GTF Score revealed a significant main effect of the Control Interface ($F(2, 234) = 33.6, p < .001, \eta^2_g = .223$; shown in Figure 4A), such that participants reported the highest familiarity with the Move ($M = 2.64, SE = 0.18$), followed by the RSM ($M = 1.83, SE = 0.13, MOVE p < .001$), and reported the lowest familiarity with Kinect ($M = 1.16, SE = 0.12, MOVE p < .001, RSM p = .001$). A between-subject effect was observed for Age ($F(2, 117) = 7.63, p = .001, \eta^2_g = .115$), such that the youngest group ($M = 2.33, SE = 0.17$) reported higher familiarity across control interfaces than the oldest group ($M = 1.4, SE = 0.17, p < .001$).

#### 4.2 Successful Hit %—Intuitive Use

Mauchly’s Test indicated that the assumption of sphericity had been violated for Successful Hit % with Gender ($W = .826, \chi^2(2) = 22.3, p < .001$) as a between-subjects factor, and so a Greenhouse-Geisser adjustment ($\epsilon = .852$) was used for its within-subjects analysis. A significant main effect of the Control Interface on Successful Hit % was revealed ($F(1.7, 201) = 94.6, p < .001, \eta^2_g = .445$), such that participants performed best with the RSM ($M = 90.2, SE = 0.53$), followed by the Move ($M = 85.3, SE = 0.72, BOTH p < .001$), and performed worst with Kinect ($M = 78.8, SE = 0.8, BOTH p < .001$). However, this effect was qualified by an interaction between Gender and the Control Interface ($F(1.7, 201) = 4.53, p = .016, \eta^2_g = .037$) for Successful Hit %. This interaction also qualified a between-subject effect of Gender on Successful Hit % ($F(1, 118) = 6.63, p = .011, \eta^2_g = .053$), such that males ($M = 85.5, SE = 0.52$) performed better across the NMCIs than females ($M = 83.1, SE = 0.77$). For the interaction between Gender and the Control Interface for Successful Hit % (shown in Figure 4B), step-down analysis revealed that the significant simple main effects between the Control Interfaces were the same for both genders. Namely, the Successful Hit % scores were significantly higher for the RSM ($MALE M = 90.6, SE = 0.59; FEMALE M = 89.3, SE = 0.89$) than they were for the Move ($MALE M = 85.5, SE = 0.8, p < .001; FEMALE M = 85, SE = 1.2, p = .002$) or Kinect ($MALE M = 80.4, SE = 0.89, p < .001; FEMALE M = 75, SE = 1.34, p < .001$), and results for the Move were also significantly higher than for Kinect ($BOTH p < .001$). A significant simple effect between genders was also revealed for the Kinect condition only, such that males performed better than females ($p = .001$).

Between-subject effects on Successful Hit % with medium effect sizes were also revealed for both Age ($F(2, 117) = 3.72, p = .027, \eta^2_g = .06$) and Combined NMCI GTF ($F(2, 116) = 3.79, p = .025, \eta^2_g = .061$). These effects revealed that the youngest group ($M = 86.3, SE = 0.74$) performed better than the oldest group ($M = 83.5, SE = 0.75, p = .026$), and that participants in the high NMCI GTF group ($M = 86.3, SE = 0.75$) performed better than those in the low NMCI GTF group ($M = 83.5, SE = 0.75, p = .023$).

#### 4.3 Intuitive Controls (PENS)

Mauchly’s Test indicated that the assumption of sphericity had been violated for perceived Intuitive Controls with Combined NMCI GTF ($W = .911, \chi^2(2) = 10.8, p = .004$) as a between-subject factor, and so...
a Greenhouse-Geisser adjustment ($\epsilon = .918$) was used for its within-subjects analysis. Step-down analysis revealed a significant main effect of the Control Interface on Intuitive Controls ($F(1.84, 215) = 36.5, p < .001, \eta^2_p = .238$), such that participants reported the highest perceived Intuitive Controls with the RSM ($M = 5.81, SE = 0.09$), followed by the Move ($M = 5.52, SE = 0.1, \text{RSM} p = .005$), and reported the lowest perceived Intuitive Controls with Kinect ($M = 4.92, SE = 0.12, \text{both} \ p < .001$). However, this effect was qualified by an interaction between Combined NMCI GTF and the Control Interface ($F(3.67, 215) = 4.81, p = .001, \eta^2_p = .076$) for Intuitive Controls (shown in Figure 4C). All Combined NMCI GTF groups reported higher perceived Intuitive Controls with the RSM ($\text{LOW} M = 5.73; \text{MIDDLE} M = 5.89; \text{HIGH} M = 5.83; \text{ALL} SE = 0.15$) than with Kinect ($\text{LOW} M = 5.14, p = .008; \text{MIDDLE} M = 4.48, p = .001; \text{HIGH} M = 5.13, p = .001; \text{ALL} SE = 0.21$). Only the higher NMCI GTF groups reported higher perceived Intuitive Controls with the Move ($\text{MIDDLE} M = 5.53; \text{HIGH} M = 5.8; \text{ALL} SE = 0.18$) than with Kinect ($\text{MIDDLE} p < .001, \text{HIGH} p = .005$). Conversely, the low NMCI GTF group were the only group that reported higher perceived Intuitive Controls with the RSM than the Move ($M = 5.23, p = .007$).

5 DISCUSSION

5.1 Familiarity and Intuitive Use

The differences between Kinect and the other conditions for Successful Hit % correspond with the differences observed for the control interface familiarity (GTF) scores, with Kinect always lower than the other interfaces for both measures, supporting GTF’s utility as a predictor of intuitive use. While more participants reported having previously used Kinect (70 of 120) compared with either the Move (30) or Racket Shell Move (0), only 13 participants reported never having used wand-based motion controls similar to Move (like the Wiimote). The reduced familiarity observed for Kinect therefore partially reflects reduced length, recency and intensity of exposure with the actual device as well as broader exposure to wand-based controls in the population.

While familiarity appears to have strongly influenced intuitive use results, an alternative explanation is that the reduced natural mapping in Kinect via the lack of a tangible object to grasp presented an incomplete mapping of the mental model for the equivalent real-life activity and tool. Admittedly, Kinect’s lower bandwidth and naturalness to map player movements to control actions potentially confounds the precise source of the differences shown. This discrepancy was highlighted by Reinhardt and Hurtienne [54], and in their experiment no difference was shown for performance across the three Kinect conditions using different physical props, though familiarity was not sampled in a way that could predict intuitive use. Broad capture of body movements using a non-tangible camera-based interface is the definable attribute of the kinesically naturally mapped control interface type [63], and in [54] the ‘prop’ was not tracked by Kinect in any condition, so their work serves more to highlight differences relevant to the perceptual benefits of non-computationally coupled tangibility. Regardless, the intuitive use differences shown for Kinect in this study reflect its game technology familiarity score and reinforce its position on the NMCI typology, while adding further weight to the argument for a more detailed classification system for natural control interfaces based on their dimensions [30, 43, 54].

In contrast to the results for Kinect, participants reported higher levels of familiarity relevant to the Move than the RSM—yet intuitive use was higher with the Racket Shell Move, even though both control interfaces used the same underlying technology to capture player movements and map them to control actions. This discrepancy could be explained by the RSM also leveraging familiarity relevant to the Move for intuitive interaction, since the control interfaces are similar and relevant knowledge could be classed in the same domain (i.e. tangible motion controls) [9]. However, intuitive use outcomes for the RSM might also have been stronger due to the higher levels of natural mapping in the control interface (exclusively defined by a more physically realistic look and feel). The more naturally mapped control interfaces likely better complete the mental model of a tennis racket for players, supporting movements more in line with the equivalent real-life activity [63]. Results for Successful Hit % therefore support the idea that higher correspondence between the conceptual and physical characteristics of a mapped interface can support a stronger performance and higher levels of intuitive interaction.

However, additional factors might have also influenced these results relating to how wrist movements were captured and mapped to the rotation of the virtual racket head during the Move and RSM conditions. During play with the Racket Shell Move, the racket head rotation was represented both virtually on screen (when visible during play) and physically (in the participant’s hand). For the Move condition, tracking racket rotation was much more difficult (although still possible) without the physical racket head; participants could check the virtual racket when it appeared on screen, yet rotation was less clear and based solely on the Move’s physical position. Thus, the RSM’s physical attributes, which contribute to its NMCI classification, might have helped participants cope better with the increased bandwidth and naturalness demands of the Move’s motion controls. It is therefore difficult (and arguably impossible) to separate the factors that contributed to this result for the RSM (e.g. clearer feedback or higher natural mapping). What is clear is that the RSM’s physical characteristics provided a perceptual benefit that improved intuitive use outcomes, compensating for any implications of reduced familiarity compared to Move.

Some of the between-subject effects observed for Successful Hit % further support the game technology familiarity instrument’s ability to predict intuitive use. The high control interface familiarity group performed better across NMCI than the group with the lowest relevant familiarity. Similarly, the youngest Age group showed a higher NMCI GTF Score and in turn a higher Successful Hit % across conditions than the oldest group. These latter effects are unsurprising given the statistics for gameplay behaviour in the broader population, including higher ratios of younger gamers compared with older gamers, with younger gamers also playing more frequently [17]. The similar effects of age on control interface familiarity and intuitive use in this study support the notion that lower levels of intuitive interaction shown by older players might be more clearly linked to technology familiarity, rather than age-related cognitive or physical decline [14, 46, 50, 51].
One result that contrasts between the NMCI GTF Score and Successful Hit %, however, is the interaction effect for Gender (shown in Figure 4b) that revealed males performed better with Kinect than females. It is possible that this difference only shows up with Kinect due to its reduced natural mapping, since higher natural mapping has been shown to provide a compensatory or equalising effect [44]. An alternative explanation is that males in the sample were able to better visualise the movements required by the game without the support of a tangible object to grasp, since some gender differences in spatial cognition are generally accepted [27]. This is supported by research that shows that males have faster response times for tasks involving mental rotation of 3D objects than females [55], potentially implicating cognitive differences rather than familiarity levels. This would explain why no such gender differences were found for the Move or Racket Shell Move (which have tangible objects to support visualisation) or in the results for the NMCI GTF Score. Nevertheless, the revised GTF measure appears to have targeted the previous experiences relevant to intuitive use or performance with the NMCI in this study, just as in its previous implementation [44]. While TennisLife Familiarity revealed no impact on intuitive use, the natural mapping model might have simply lacked the capacity to capture and effectively leverage subtler elements of embodied tennis knowledge (such as motions related to foot movement and precise shot selection).

5.2 Perceptions of Intuitive Controls

Control interfaces with higher natural mapping were generally perceived as more intuitive, yet the characteristics of the NMCI determined the point at which those with different levels of control interface familiarity perceived them as such. Specifically, the NMCI dimensions of realism (tangibility, form and aesthetics) and bandwidth (or control fidelity) appear to have influenced these perceptions. For those with more control interface familiarity, increases in realism (tangibility) and bandwidth (Move over Kinect) were enough to facilitate perceptions that controls were more intuitive, yet for low GTF players, greater realism (as with the RSM over the Move) was also required for this boost to perceptions of intuitiveness. Mental model matching through increased realism in the control interface, along with relevant familiarity, thus also appears to play an important role in perceptions of intuitive use. Similar experiences (GTF) might be driving perceptions of intuitiveness for players with high familiarity, while low-familiarity players might rely more on greater realism in the control interface to match their mental model for the activity. However, results also suggest that natural mapping plays an important role overall, potentially counteracting lower relevant familiarity (NMCI GTF scores) with the Racket Shell Move (compared with the Move) to facilitate higher perceptions of intuitive use. This appears to be especially true for players with less overall control interface familiarity, though more naturally mapped controls generally supported higher perceived intuitive use across the whole sample.

While no effects were found for age and gender on perceived Intuitive Controls, familiarity with relevant control interfaces revealed an effect in this study as with previous work [44], further reinforcing the relationship between familiarity and intuitive use [13]. TennisLife Familiarity showed no effect, in contrast to the RaceLife familiarity measure in [44], suggesting that this effect might depend on certain gaming contexts, or potentially on the level of realism possible through natural mapping in those contexts. It is worth noting that TennisLife familiarity did show an influence on perceptions of performance as captured by the Competence construct from PENS [43]. Here, those with greater experience with the equivalent real-life activity reported feeling more competent across the control interfaces. Thus, measuring real-life experience is arguably relevant to examination of the broader player experience when using natural control interfaces, as suggested by prior work [26, 44, 58], even if control interface mapping fails to support transfer of these skills into game play results. Along with the implications revealed by the interaction of Combined NMCI GTF for perceived Intuitive Controls, these differences highlight further distinctions related to the dimensions of natural mapping and the classification of NMCI, as explored in [43].

6 SUMMARY, LIMITATIONS AND FUTURE WORK

Overall, more naturally mapped control interface types were shown to offer significantly improved intuitive interaction outcomes over interfaces with less natural mapping, even when all the NMCI could be singularly categorised as ‘motion controls’ and the differences between control interfaces was limited to physical realism (i.e. Racket Shell Move vs. Move). The differences shown for intuitive use contrast with other research on tennis-related video games that measured performance with different NMCI, which either showed no effects [54] or higher performance for control interfaces with limited interaction fidelity [30]. The objective intuitive use results are relatively novel, both by suggesting that natural mapping can support a stronger performance and showing a strong connection with player characteristics, especially game technology familiarity. As with its first implementation, the revised GTF measure proved to be an effective predictor and qualifier of intuitive interaction results [44]. This was shown not only through the Combined NMCI GTF effects, but in the correspondence between the main and other player characteristic effects revealed for the dependent variable GTF Scores and the intuitive use measure.

Participants also reported the highest relevant familiarity with the more naturally mapped control interfaces (Move and RSM), and results for the subjective and objective measures of intuitive interaction reflected this. Participants reported the lowest familiarity relevant to Kinect, performed the worst with this device and reported that it offered the least intuitive controls. Familiarity thus broadly informed intuitive use, but when exceptions occurred, they were attributable to the benefits of increased natural mapping (or the drawbacks of limited natural mapping) in the control interface. This offers additional support for the notion that natural mapping (or certainly increased bandwidth and naturalness) can be leveraged in design to increase the potential for intuitive interaction [9, 37], which helps to clarify the supposed intuitive benefits of natural user interfaces. As with previous work [44], the real-life familiarity measure revealed no influence on the objective intuitive use measure, suggesting that the tested control interfaces did not leverage (or allow for the transfer of) relevant real-life knowledge.
in a way that significantly improved objective performance results. The influence of real-life familiarity on intuitive interaction thus appears to be limited to perceptions of intuitive use, although this could change as advances in technology allow control interfaces to more accurately or fully simulate the equivalent real-life activity.

Given the first author’s recent work that more clearly explicates the dimensions of natural mapping relevant to the effects of NMCIs [43], future work should seek to consider the individual influencing effects of physical realism, bandwidth/fidelity and correspondence/naturalness. The revised GTF approach to sampling previous experience and other novel procedures employed in this research represent a contribution that also requires further validation, both for intuitive interaction work with video games and to evaluate these tools for games user research. We chose to prioritise control over our experimental conditions in the current study and the relatively short play times and the laboratory environment used limit our ecological validity (though we attempted to mitigate these factors, for example, by simulating a natural lounge room). The work here is also limited by the gaming context explored and needs to be replicated in other genres besides racing and sports games, especially those with less literal control interface mappings. Similarly, we were not able to represent all controller types in the current study and future research could usefully assess the full range of controls interface types concurrently. Finally, our sample consisted of a majority of male participants and this obviously limits the generalisability of our findings – future research should seek to confirm our conclusions with a more demographically balanced sample.

There is also a growing need to transfer these lessons to the way in which natural controls are applied and evaluated in augmented and virtual reality games, where their use has become extensive, as well as the generally subtler ways in which motion controls are being utilised in contemporary video games. Similarly, these findings are particularly applicable to exergames design and research, where natural and potentially intuitive modes of interaction are readily and frequently utilised.

7 CONCLUSION
Our work contributes three major findings in terms of the influence of naturally mapped control interfaces on intuitive interaction. First, it suggests that intuitive use with NMCIs in video games is broadly in line with relevant control interface familiarity levels (i.e., generally, the more familiar people are with similar technologies the more intuitive they will find the corresponding control interface). That relevant familiarity was a reliable predictor for the occurrence of intuitive use with video games supports and extends this finding from existing intuitive interaction research [9, 12, 22, 46, 50, 51]. Second, this work supports the notion that control interfaces with higher natural mapping might also offer compensatory effects for some types of players (e.g., those with less gaming experience and lower control interface familiarity). Finally, player characteristics like control interface familiarity (i.e., GTF) may shape perceptions of intuitive interaction with different NMCIs according to their dimensional attributes. For those with higher domain knowledge (frequent players), intuitive interaction might increase more dramatically in the middle of the natural mapping continuum, where NMCIs gain tangibility, with limited further gains for NMCIs with higher natural mapping due to increased aesthetic realism. Conversely, for those with limited relevant familiarity (more casual players), the intuitive interaction gains of NMCIs might not be substantial until the control interface gains this greater physical realism (and a more complete representation of the appropriate mental model) at the highest level of natural mapping. This was clearly highlighted by the differences shown between the Move and RSM conditions across measures, with the same fundamental technology producing different results for both objective and perceived measures of intuitive use, based solely on the addition of a plastic and foam shell. Thus, while natural mapping in motion controls can facilitate intuitive interaction, at least with more literal metaphors like those used in a tennis video game, not all NMCIs are created equal — especially in the eyes of different player groups. These findings on the relationships between player characteristics and natural control interfaces, as well as the proposed methods to evaluate them, should be further explored by games researchers and provide an important potential avenue for game designers seeking to better leverage different types of controls for their target audience.

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