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RESEARCH PAPER

Hyper-Intense Interaction Controls Heuristics (HIICH) in RPGs, FPS, TPS genre smartphone Games

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ABSTRACT

Hyper-Intense games are characterized by difficult gameplay and highly engaging interaction. These interaction-heavy games often pose extreme complexity for virtual input controls, hence, resulting in difficult interaction, especially in smartphones where the primary input medium is touchscreen. Touchscreen controls lack tactile feedback which hinders playability in genres like First/Third Person Shooter (F/TPS). The lack of context-specific heuristics to evaluate hyper-intense interaction yield usability issues in such games. Using a seven staged methodology, a heuristic set for evaluation of virtual controller is devised; evolved and validated over multiple iterations. The development of the proposed heuristics followed an iterative process, driven by designing a virtual controller within a smartphone game. This is followed by a qualitative analysis and a controlled experiment to compare the effectiveness of proposed heuristics with general heuristics. Findings of the validation stage indicate that the proposed heuristic set (HIICH) is capable to uncover more usability and interaction issues.

Keywords: FPS/TPS/RPGs, Heuristics, Hyper-Intense Interaction, Smartphone Games, Usability, Virtual Controller.

INTRODUCTION

Heuristic evaluation is a popular and cost-effective evaluation method among software and game development organizations, help to uncover usability problems (Abulfaraj & Steele, 2020; Ahmed et al., 2022; Aker, Rızvanoğlu, & İnal, 2020; Ali, 2022; Langevin et al., 2021; Lam, Hoang, & Sajjanhar, 2021; Paavilainen, 2010; Johnston & Pickrell, 2016; Black, Morris, Akinluyi, & Kay, 2023; Mohamed & Jaafar, 2010a) This method was initially introduced by Nielsen (Mohamed & Nielsen, 1990; Nielsen & Phillips, 1993; Senap & Vee, 2019)in early 1990s and he estimated that heuristic evaluation reveals about 75%-80% usability problems with lesser human resource investment. However, the generic nature of Nielsen's heuristics makes them less effective for

specialized software like embedded systems or smartphone hyper-intense games. As a result, a number of context-specific heuristics were introduced overtime, for example, a study proposed a refined set of 9 heuristics addressing user experience in web services (Väänänen-Vainio-Mattila & Wäljas, 2009b; Väänänen-Vainio-Mattila & Wäljas, 2009a), another study (Inostroza et al., 2016) proposed heuristics targeting mobile apps. Similarly, another research (Desurvire et al., 2004; Desurvire & Wiberg, 2009) suggested heuristics for computer games.

Over the past two decades, computer games have evolved to complex and advance forms (Pulis, 2015; Soomro, Ahmad, & Sulaiman, 2014). Hence, specialized, domain specific heuristics regarding games were developed over the time including heuristics proposed by the studies (Ahmed et al., 2022; Clanton, 1998; Desurvire et al., 2004; Federoff, 2002; Johnston & Pickrell, 2016; Soomro, Ahmad, & Sulaiman, 2014). However, different types of games have unique pace and interaction style, hence general heuristics for every game were found to be less effective. Similarly, it has been recognized that the hardware on which the game is played, significantly alters the user experience and there is a need of hardware specific game heuristics. A number of such heuristics have been proposed including heuristics for mobile based games (Soomro, Ahmad, & Sulaiman, 2012; Soomro, Ahmad, & Sulaiman, 2014).

It is reasonable to divide games into two main categories from the player's interaction perspective: games with intensive gameplay (FPS, TPS, RPGs) and games without intensive gameplay. Games involving complex and engaging user interaction during gameplay are also referred as Hyper-intense games. Hyper-Intense games are fast-paced and interaction-heavy action games such as Brothers in Arms and Covert Strike. While the games with non-intensive gameplay have simple user-interaction and can be referred to Casual or Hyper-Casual games such as, Temple Run, Angry Birds. Moreover, gaming platforms can broadly be divided into the following two types: platforms with a dedicated input device such as a keyboard or joystick and platforms without a dedicated input device e.g. a touch screen device where the input and output both are handled by the same hardware. Overall player experience depends upon both the genre of game and the platform on which the game is played.

	Casual/Hyper-Casual / Low Intensity Interaction	**Hyper-Intense / High Intense User Interaction**
Hardware with Dedicated Input Controller (PC/Laptop/Xbox, PS)	Super Mario, Dangerous Dave	Project IGI 2, Covert Strike, Assassin Creed, GTA, NFS
Hardware without Dedicated Input Controller (Touchscreen/Smartphone Interfaces)	Teeter, Angry Birds, Temple Run, Subway Surfer	Brother In Arms, Call of Duty (Android versions)

Table 1. Game Categorizations in dimensions of Interaction Intensity Level

Designing an appropriate interaction paradigm for a hyper-intense (interaction-heavy) games like First Person Shooter (FPS), Third Person Shooter (TPS) and Role Playing Games (RPG) is most challenging when played on a hardware lacking a dedicated input device. Hence, in this context, a broad categorization for games can be Hyper-Intense interaction and Casual/ Hyper-Casual games involving low intensity interaction, as summarized in Table 1.

In this paper, we developed a comprehensive set of heuristics set named as Hyper-Intense Interaction Controls Heuristics (henceforth HIICH) that addresses the usability of smartphone games when it comes to interaction-heavy genres like Action/Adventure, First/Third Person Shooting and Role Playing games. Being context specific and hardware specific; these heuristics aim at better user experience and uncovering usability issues at earlier stages in hyper-intense games in smartphones.

Section 2 builds a background for this research work, followed by related work based similar studies in human-computer interaction and game design and development field. Research methodology is discussed in Section 3. In the subsequent section, proposed heuristics set (HIICH) is presented along with explanation and example scenario. Section 5 presents validation phase and a controlled experiment in comparison of proposed and traditional heuristics., followed with sections for conclusion & future research directions and acknowledgments.

BACKGROUND AND RELATED WORK /LITERATURE REVIEW

Gaming

Electronic games are a common source of leisure (Haberlin & Atkin, 2022), entertainment, curtailing social isolation (Taheri & Weissman, 2021), education (Shi, Zhou, & Wang, 2021) and rehabilitation (Burdea, 2012). Gaming industry is flourishing day by day (Mylly, Rajanen, & Iivari, 2020) and new perspectives like augmented reality (Lv et al., 2015), brain-computer interfaces (Diya et al., 2019) and learning in virtual reality (Chen & Hsu, 2020) are emerging. Successful gaming experience is highly dependent on game usability.

Usability in game development

Usability is a relative term and different researchers presented different definitions of usability depending on context. Standard ISO 9241-210 (Ergonomics of human system interaction-Part 210, 2009) defines usability as the extent to which a service or product or system can be used by users to achieve specified goals in an efficient, effective and satisfying manner. Nielson considers usability as a set of principles, paradigms, and attributes (Mohamed & Nielsen, 1990; Nielsen & Molich, 1990; Nielsen & Phillips, 1993) Another study introduced a PACMAD usability model (Harrison, Flood, & Duce, 2013) and identified attributes of usability including *effectiveness*, *efficiency*, *learnability*, *satisfaction*, *memorability*, *errors* and *cognitive load*. Hence, usability is difficult to comprehend and it is hard to create one generalized definition for all domains (Mylly, Rajanen, & Iivari, 2020; Weichbroth, 2020; Rusu, 2015) rather it can be defined relative to context and system properties under consideration.

Heuristic Evaluation as a method

Identifying usability problems results in improving user experience (Rehman et al., 2021; Bashir & Farooq, 2019). Heuristic Evaluation (*HE*) is an effective and broadly used method to identify usability problems in multiple fields of software, apps and hardware. For instance; in a serious game equipped with adjusting difficulty level in accordance with user's bio signals (Karavidas, Apostolidis, & Tsiatsos, 2022), the authors used heuristic evaluation method to highlight usability problems. Similarly, the study (Ali, 2022) used Heuristic evaluation to identify usability issues in Fintech applications. Keeping in view the generic nature of Nielsen's heuristics,

another study (Benaida, 2023) attempted to extend the original heuristic set and proposed 14 heuristics and 42 sub-heuristics. The study (Guo, 2023) emphasized on easy-to-use heuristics and outlined heuristic evaluations in context of virtual reality (VR). In study (Carmichael & MacEachen, 2017), the authors used heuristic evaluation method in educational context. The study (Haberlin & Atkin, 2022) used heuristic evaluations and semiotic evaluations to analyze usability in apps for autistic end users. Another study (Sanchez-Adame et al., 2019) proposed five usability heuristics specifically for chatbots. Similarly, in the study (Langevin et al., 2021), proposed heuristics for conversational agents. The study (Quiñones & Rusu, 2017) conducted a systematic review of existing heuristics and identified that two basic approaches to devise heuristics can be; based on existing heuristics and a methodology. Two prominent categories of issues; *interface* and *functionality* are observed in (Subrata Sandhiyasa & I Gede Aris Gunadi, 2022) among the identified usability problems. Usability issues in audio guides and websites were uncovered in a study (Lam, Hoang, & Sajjanhar, 2021) using heuristic evaluations. Another study (Johnston & Pickrell, 2016) proposed a set of 8 heuristics for mobile applications intended for technicians.

Heuristic Evaluation in Games

Observing the inefficiency of general heuristics in uncovering context specific usability issues, the study (Ahmed et al., 2022) presented heuristics for Arab mobile games. In (Desurvire et al., 2004), the authors concluded a set of 43 heuristics (*HEP*) based on usability problems identified in the literature review and game designers. The study classified heuristics into four categories of game story, gameplay, game mechanics, and usability. Furthermore, authors presented game usability heuristics (*PLAY*) (Desurvire & Wiberg, 2009) and presented a comprehensive list of 43 game design principles.

Another study (Bertini, Gabrielli, & Kimani, 2006) identified benefits of heuristic based evaluations and proposed a set of 8 usability heuristic relevant to mobile computing. Similarly, a customized set of heuristics in comparison with Nielsen's heuristics is used in (Cunha, Machado Neto, & Pimentel, 2013) to evaluate a video annotating tool. This customized set of 11 heuristics was intended for identifying usability problems in mobile interfaces.

In order to comprehend different aspects encompassed in general heuristics (Nielsen & Molich, 1990; Nielsen & Phillips, 1993; Senap & Vee, 2019) and to help novice evaluators; the study (Abulfaraj & Steele, 2020) proposed a simplified version of general heuristics. This simplification involved detail explanation of each heuristic. In the study (Daud, Mokhtar, & Mohd, 2016) authors identified the need for context specific heuristics for touch screen interfaces. A comparison of two heuristics set in (Korhonen, Paavilainen, & Saarenpää, 2009) concluded that heuristic evaluation can uncover both Interface and Playability issues. This study used a set of 12 playability heuristics previously defined in (Korhonen & Koivisto, 2006) intended for usability interfaces. These heuristics were based on the context of mobile use, problems identified in literature and game evaluations. The author also presented heuristics for multiplayer online games (Korhonen & Koivisto, 2006).

The study (Black et al., 2023) suggested that heuristic evaluation efficient in terms of cost and time and concluded that it helped in uncovering usability issues in medical device; oximeter. A set of 40 heuristics for video games were proposed (Federoff, 2002) with similar classification as Clanton (Clanton, 1998) i.e. gameplay, game mechanics, and game interface.

Another study investigated usability heuristics (Mohamed & Jaafar, 2010a) in the context of educational games and introduced set of 43 heuristics attributes (*PHEG*) (Mohamed & Jaafar, 2010b) divided into the following categories: interface, education, content, multimedia, and playability. In the study (Pinelle, Wong, Stach, & Gutwin, 2008) authors summed up a set of 10 usability heuristics for video games and later on introduced additional 10 heuristics (NGH) (Pinelle, Wong, Stach, & Gutwin, 2009) for the genre of multiplayer networked-games. The complex genre game interactions in smartphone are considered by (Yoon-Hyun, 2015) and found that flick and multi-touch based interaction is more usable in virtual game controllers. Heuristics for mobile interfaces are also devised in another study (Neto & Pimentel, 2013). Based on meta data, the study (Yanez-Gomez et al., 2019) proposed MUSE; a tool to rebuild customized heuristics for specific classifications in games.

Similarly, 16 usability guidelines were proposed (Nasr, Alsaggaf, & Sinnari, 2023) to analyze mobile health (*mhealth*) applications. In the study (Papaloukas, Patriarcheas, & Xenos, 2009) the authors presented a set of new usability heuristics for video games based on pre-existing game reviews. Similarly, video games were reviewed by (Langevin et al., 2021) in the context of social games and proposed 10 heuristics for social games evaluations.

Using a survey among game players, the study (Robson & Sabahat, 2020) emphasized the need of domain specific heuristics and proposed a heuristic set for the genre of racing mobile game. Similarly, the study (Balakrishnan, 2008) identified that generic evaluations are insufficient to cover all domain specific aspects in multi-touch interactions. The study (Senap & Vee, 2019) analyzed existing heuristics components and suggested the need of context specific heuristics for mobile educational games (*MEGs*). 14 heuristics (*EUHSA*) were devised (Bashir & Farooq, 2019) for usability evaluation in smartphone applications.

Gap of FPS/TPS/RPG genre specific heuristics addressing intense-interaction

Smartphone interfaces differ from traditional software interfaces like Content Management Systems and Information systems; in terms of interaction paradigm, hardware being involved and playability. As suggested in (Aker et al., 2020) various gaming platforms offer unique playability experiences.

The study (Soomro, Ahmad, & Sulaiman, 2012) postulated a set of 10 heuristics named as Playability Heuristic Evaluation System (*PHES*) for mobile games and later conducted an evaluation of games (Soomro, Ahmad, & Sulaiman, 2014) using PHES in comparison with traditional heuristics. Another relevant study (Inostroza et al., 2016) presented a set of 12 usability heuristics for smartphone named as SMArtphone uSability Heuristics (*SMASH*). *SMASH* identified key challenges in smartphone user interface design and addressed them.

Games are now played increasingly on smart platforms; they, however, pose different challenges like small screen size, lack of tactile feedback (Bertini, Gabrielli, & Kimani, 2006; Soomro, Ahmad, & Sulaiman, 2010, May 6; Baldauf et al., 2015) limited input methods, relatively low processing capabilities as compared to PCs and consoles (Pelegrino et al., 2014, November). General heuristics are unable to answer context specific issues like interfaces in games, especially when it comes to genre-specific usability problems. Although many context-specific usability heuristics (Ahmed et al., 2022; Langevin et al., 2021, May 6; Inostroza et al., 2016) have been developed but still the literature lacks for a genre specific usability heuristics for FPS/TPS/RPG that can address user-interaction in smartphone games. This study presented a heuristic set to fulfill the gap of context-specific for genre of FPS/TPS/RPGs and hardware-specific

(touchscreen/smartphones) evaluations that can result in better playability, interaction and game design.

RESEARCH METHODOLOGY

In this study, we adapted a methodology by (Quiñones & Rusu, 2018) which had been used in a similar study (Haberlin & Atkin, 2022). Our methodology is a contribution in (Quiñones & Rusu, 2018) to develop the proposed heuristics (*HIICH*). The study (Quiñones & Rusu, 2017) also recommended to follow a methodological approach while devising heuristics. This methodology involves following stages:

Exploratory Stage (Literature & Industry):

The first stage involved collecting usability and user interaction problems in mobile games from both the existing literature and informal interviews conducted with active gamers. These gamers had been actively playing multiple RPGs, FPS / TPS genre games on smartphones. This stage focused on both literature and industrial feedback. This stage helped in exploring current problems in playability, user interaction, game aesthetics and game mechanics in smartphone mobiles games.

Descriptive Stage:

The second stage involved summing up of evidences, usability issues and challenges being identified from literature and augmented it with information collected from gaming community. This stage involved outlining and prioritizing usability issues in smartphones in context of games. In light of these issues and challenges matrix, a preliminary set of heuristics was outlined.

Correlation Stage:

This stage involved iterative development and improvement of heuristics using empirical evaluations. A set of virtual controller was designed for a FPS Android game in the first iteration. Gamers then played with the freshly designed virtual controller to identify usability problems by an informal inspection. Problems found in an inspection were mapped to heuristics previously identified; if a problem couldn't be mapped to a specific heuristic then the heuristic set has been updated to address identified deficiency. A total of 6 iterations were carried out, which resulted in 5 different versions of the virtual controller and 6 updates in proposed heuristic set. Figure 1 represents different versions of virtual controller developed during these iterations. The first version of heuristics is devised as a result of this stage.

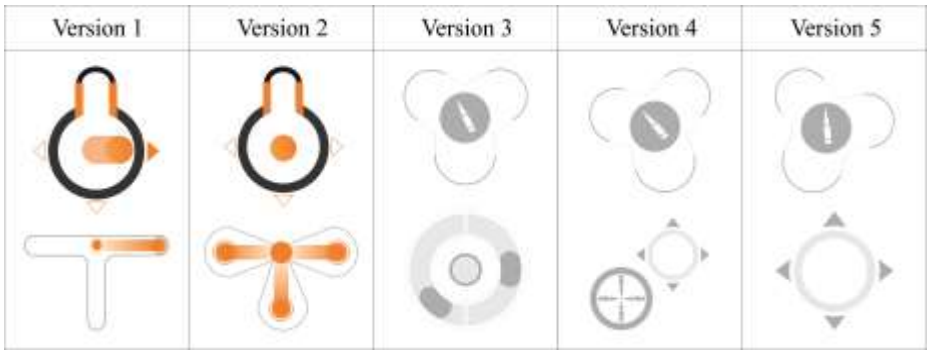

Fig. 1. Versions of Virtual Controller (VC) created during Correlation stage of methodology

***Selection Stage**:*

This stage involved further modification in the first version of heuristic set *HIICH* based on outlined usability aspects.

Specification Stage:

This stage involves formal specification of usability heuristics for smartphone interaction controller after usability issues mapping and (or) modification to a specified heuristic.

Validating Specification:

In this stage, we performed formal validation of proposed heuristics for hyper-intense mobile games using a qualitative approach. The core objective of this stage is to devise a comprehensible specification of heuristics.

A formal review of proposed *HIICH* was carried out by 3 industrial experts with expertise in QA of smartphone games. Each heuristic's Definition and Explanation was reviewed against Understandability, Clarity, and Consistency. These attributes were adopted from a similar study (Weichbroth, 2020).

A five point Likert scale containing Strongly Disagree to Strongly Agree was used against each of the heuristics and for each attribute (*Understandability*, *Clarity*, and *Consistency*). This resulted in a questionnaire comprising of 36 questions. The procedure followed with open-ended questions regarding each heuristic to get more insights and suggestions for improvements. Based on the findings, the proposed heuristic set *HIICH* is modified.

The majority of heuristics were found to be *understandable*, *clear* and *consistent*. All of those heuristics were re-specified, which had uncertainty or multiple opinions among evaluators about any of the quality attributes (*Understandability*, *Clarity*, and *Consistency*). Fig. 2 shows summarized result of opinions of industrial experts against understandability, clarity, and consistency of each specified heuristic.

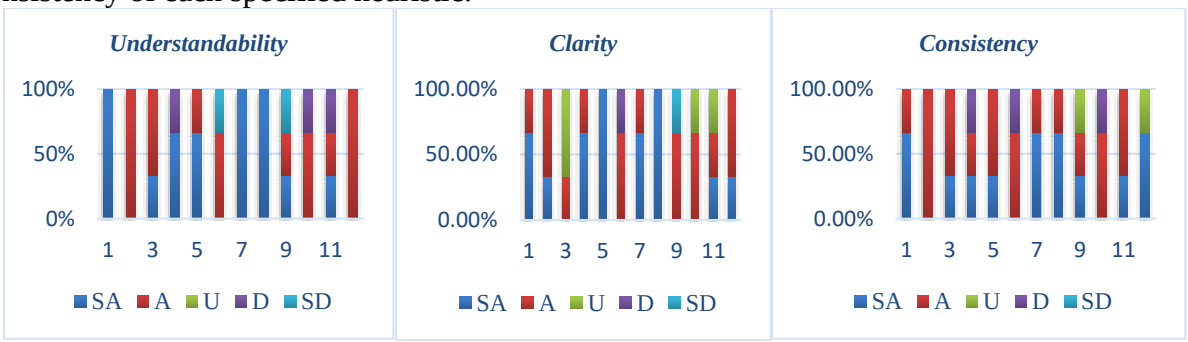

Fig. 2. Reviewer's opinions for Understandability, Clarity and Consistency of each heuristic in HIICH

Validation Stage:

This stage encompassed a formal validation of proposed heuristics set *HIICH*. A controlled experiment was conducted in order to evaluate how effective proposed heuristics are in finding out usability problems in comparison to traditional / general heuristics. This experiment comprised of heuristics evaluations of an Android game *Metal Soldiers* by 48 gaming professionals having smartphone game development and evaluation experience. Each participant evaluated the game

using both of Nielson's heuristics and proposed set of heuristics. The results of this controlled experiment were statistically analyzed. The validation stage is discussed in detail in next section.

Refinement:

Based on the results of the previous stage we refined the heuristics to conclude proposed final optimized set of heuristics.

This stage is followed by establishing liaison of each proposed heuristic with individual usability constructs (Efficiency, Effectiveness, Learnability, Memorability, Satisfaction and Cognitive Load). This liaison signifies the impact of proposed heuristics in usability of hyper-intense smartphone games. Following illustration Figure 03 explains the methodology.

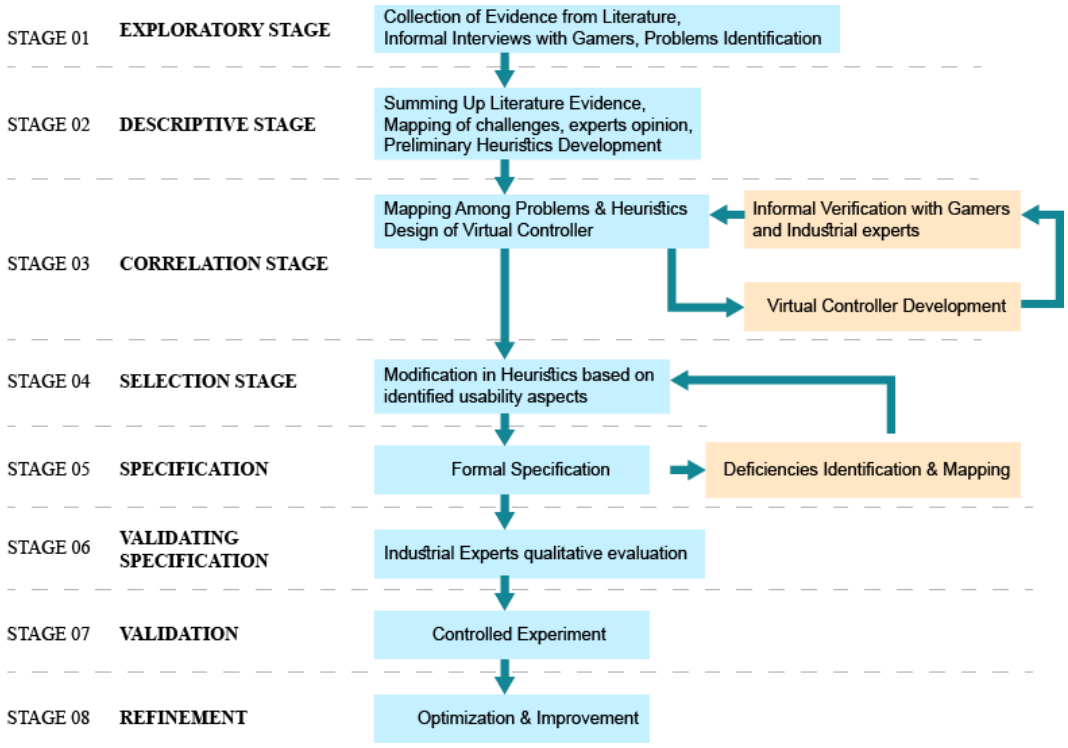

Fig. 3. Methodology being adapted for HIICH.

SPECIFYING HEURISTICS

Heuristics Definitions, Explanation, Example Scenario

This section encompasses formal specification of proposed Hyper-Intense Interaction Controls (*HIICH*) Heuristics along with their description and an example scenario. Table 2 presents summarized definitions of proposed heuristic set:

Identifier	Hyper-Intense Interaction Control Heuristics (HIICH)
HIICH 1	Multiple touch controls should be unified, equipped with integrated-transitions, allowing maximum operations rather than devising separate controls.

HIICH 2	The mechanics of a touch control or control's state-transitions should be simple and transferable to muscle memory.
HIICH 3	Number of on-screen controls for interaction with games should be minimum.
HIICH 4	On-screen interaction buttons / touch Control (s) / virtual controller should have design metaphors indicating control purpose or interaction outcome.
HIICH 5	Augment sensor input with touch based controls, favor sensory input over separate control design.
HIICH 6	Positioning of an input button /touch control / virtual controller on screen should be in accordance with reachable sections of screen-grid and frequency of use.
HIICH 7	Favor in-game actions or user-assistance over a separate touch control or adding on-screen input button.
HIICH 8	Display a touch control / input buttons / virtual controller on screen only when its needed in current game state.
HIICH 9	Hue of a touch control / input buttons / virtual controller should not stand out in a game scene.
HIICH 10	Graphics of touch control / input buttons / virtual controller should be kept minimalistic, translucent and meaningful.
HIICH 11	The size of touch control / input buttons / virtual controller should be proportionate to screen-space and average human thumb touch size.
HIICH 12	Feedback(s) / Prompts (s) for game user should be generated whenever a control's state changes.

Table 2. List of courses and their tag numbers

HIICH 1: When it comes to intensive game plays, player has to focus and find relevant control to perform multiple operations. This can result in a screen full of input controls to perform simultaneous operations like *walk/move, turn around, fire, couch* etc. Rather than designing a separate control for each game operation, multiple controls can be unified to make a single, integrated input control. This heuristic emphasizes to design unified virtual controller with multiple mechanics or state transitions allowing a user to perform multiple game operations under single thumb and constant screen contact. Fig 4 depicts transition mechanism of a unified virtual control that allows four different states and three input operations under single control.

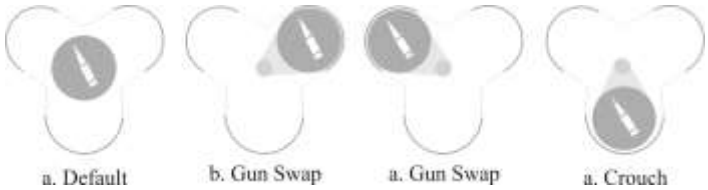

Fig. 4. Versions of Virtual Controller (VC) created during Correlation stage of methodology.

HIICH 2: State transitions or virtual control's mechanics should not pose complex patterns for touch input. Control mechanics work along easy to perform state transitions and within physical capabilities of user input. Game interaction using simple control mechanics or transitions are less error prone. An improved user experience can be accomplished if state transitions or mechanics of

a control are easily transferable to muscle memory. Fig 5 presents relatively simple and easy mechanics of a unified virtual control in comparison of complex angular movements.

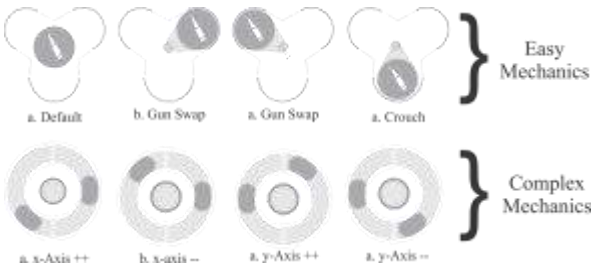

Fig. 5. Control Mechanics and state transitions

HIICH 3: Accurate inputs while playing a hyper-intense game and efficient utilization of screen space is crucial in FPS, TPS, RPG genre games where a lot of information is continuously displayed to game user. The interaction complexity intensifies with the increase in number of on-screen controls, hence minimum controls are suggested.

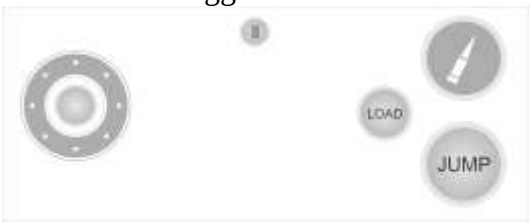

Fig. 6. Multiple Controls

HIICH 4: Controls should exhibit graphical design indications to illustrate their intended purpose or the outcome of the control operation. An ambiguous design of control will affect understandability of control. Graphical indications on controls can guide player about intended purpose and game operation. Fig. 7 shows virtual controls / on-screen buttons with design metaphors expressing about their intended purpose.

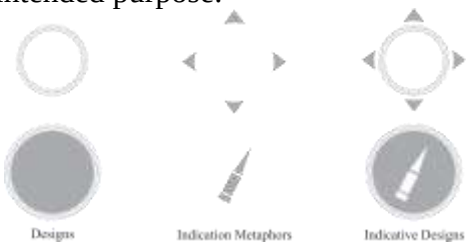

Fig. 7. Creating Indications on a Control to express its intended purpose / game operation

HIICH 5: Augmenting sensor based input in the interaction paradigm can help in minimizing number of controls, while relieving screen space. Besides devising input operations like auto-gun-reload in an FPS game, game designers can use sensor based aiming in FPS/TPS games.

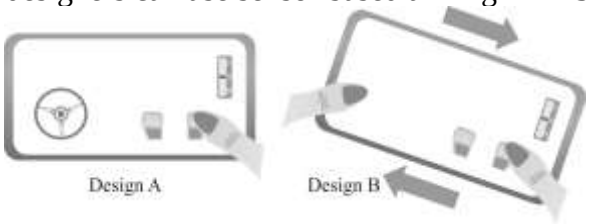

Fig. 8. Augmenting sensor input for vehicle steering operation in FPS terrain rather than an onscreen steering control

HIICH 6: Proper positioning of an input control on screen makes it more usable, while poor placement can make it difficult to use and hinder playability. A control should be positioning can be improvised by considering areas/sections of screen grid which are most reachable for fingers and (or) thumbs. When multiple input controls are present, they should be positioned based on the frequency of use, with the most frequently used controls placed in the most accessible areas.

Fig. 9 shows screen grid sections and control positioning related to optimum reach of thumbs in landscape view.

Fig. 9. Positioning of Control

HIICH 7: Having a separate control for every user action in a game would result in a large number of input controls. This can lead to a cluttered interface and the game becomes harder to play. Adding assisted operations like *auto gun-reload* operation, *auto-movement* in a particular game terrain will help in less on-screen input controls. Fig. 10 shows a separate control was incorporated in game to perform Gun-Reload operation which could have been avoided if auto-reloading assistance was provided within the game design.

Fig. 10. A separate Reload control can be avoided by devising auto-reload operation as user assistance in the gameplay

HIICH 8: If an input control is needed only in specific time instances during the game play, then a continuous availability can hinder effective interaction. Continuous display will occupy screen space and user can also get confused during intense game play. This heuristic shall help in efficient screen utilization and scene view enhancement.

Figure 11 presents an example scenario, the input control fire can only be displayed on screen when a combat is expected in the current game scene, if the player has just to pass the terrain or cross a river or bridge, it can be omitted till the time its needed or a combat is expected.

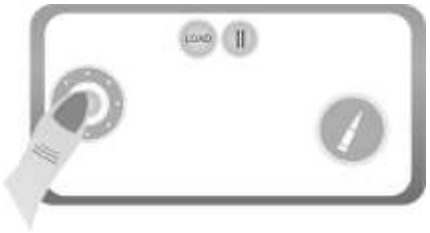

Fig. 11. Displaying a Fire operation controls only when it is needed in current game scene

HIICH 9: Hue plays an important role in gaining user attention to specific game objects or scene elements. The Hue /color shading of input controls should not stand out in a game scene; rather they can be well blended in the scene by controlling opacity/ translucency. This can help in minimizing user distraction from game scene elements. Such distractions can cause input errors, resulting in a set of less effective controls / on-screen virtual controller. A simple judgment can be based on squint test. Shades of gray color with transparency can serve the purpose.

HIICH 10: This heuristic suggests that overcooked graphics or roughly designed touch / input controls not only cover useful screen area but can potentially cause errors and user distraction from game scene. This heuristic suggests to keep the design of an on-screen control as minimalistic as possible. Designer can use Empty Spaces and Transparency within controls to give a see-through experience of the game scene. Only relevant design metaphors can be presented to user, this will increase game scene visibility and decrease screen coverage or cluttering by controls.

To avoid the ambiguity about the level of minimalism while designing a touch control, designers can follow maximum possible reduction of extra information in the graphic design while keeping the design intuitive.

Fig 12. demonstrates a touch control for navigation in game terrain in comparison with a possible minimalistic version.

Fig. 12. A noisy navigation control (A) is converted to a minimalist control (B)

HIICH 11: The gaming community involve different age groups and it is evolving day by day which presents different physical capabilities of across the user base. Size of control becomes a critical issue when it comes to Fat finger problem, small Screen-space and hyper-intense gameplay. This heuristic suggests to keep the touch control size proportionate to *screen-space* and *average human thumb size* covering a major segment of potential users. Instead of inefficient screen-space for Fat Finger Problem or minimizing control usability for majority of users; an optimum control size can help in enhancing game usability. Apple suggests a minimum size of touch control to be 44 x 44 points (Layout, n.d.). A study (Balakrishnan, 2008) estimated mean thumb circumference of males as 5.8 cm with a deviation of ± 0.75. It also calculated female's thumb circumference to be 5.4 cm with a deviation of ± 0.58. Another research (Pekka & Karlson, 2006) suggests a touch target be 9.2 mm for single target task and 9.6mm in the case of multiple target tasks. Furthermore, an anticipation can be made over different potential age groups among the target audience and a criterion range for the suitable size of control can be inferred.

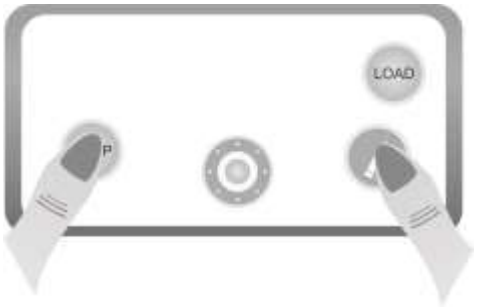

Fig. 13. Feedback(s) / Prompts (s) for game user should be generated whenever a control's state changes

HIICH 12: Change in the state of a touch control or a state-transition within a unified virtual controller, during interaction with the game should be communicated adequately to users via *sounds*, *visual effects*, *vibrations*, *avatar's responses* etc. Touch based input controls or virtual controller lack for haptic or tactile feedback as compared to hardware based input buttons or game controllers (Hoggan et al., 2008, April 6; Baldauf, 2008; Yoon-Hyun, 2015). This lack of tactile feedback can be partially overcome by generating vibration/sound based feedbacks to a user; whenever a touch control is triggered. Fig. 14 demonstrates a scenario where a visual feedback is provided to user along with phone vibration:

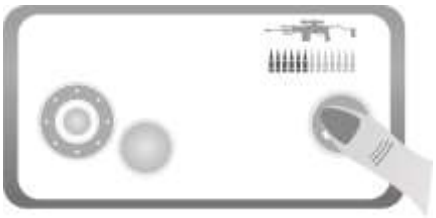

Fig. 14. Prompts / Feedbacks

Heuristics Liaison with Usability Constructs

Usability has been defined as a construct of multiple attributes (Federoff, 2002; Harrison et al., 2013; Pinelle et al., 2008). This section establishes the association of each of the proposed heuristic set with usability constructs identified in relevant usability models including PACMAD usability model (Molich & Nielsen, 1990) and others (Nielsen & Molich, 1990; Nielsen & Phillips, 1993; Senap & Vee, 2019). Table 4 establishes a relationship between different usability constructs and a particular proposed heuristic. Table 3 expresses that each heuristic impacts one or more usability constructs.

Heuristic	Efficiency	Effectiveness	Learnability	Memorability	Satisfaction	Errors	Cognitive Load
HIICH_1	✓	✓	✓	✓	✓	✓	✓
HIICH_2		✓		✓	✓	✓	✓
HIICH_3	✓	✓	✓	✓		✓	✓

HIICH_4		✓	✓	✓	✓	✓	
HIICH_5	✓					✓	✓
HIICH_6		✓	✓		✓	✓	
HIICH_7	✓					✓	✓
HIICH_8	✓	✓					✓
HIICH_9		✓					
HIICH_10	✓	✓	✓	✓	✓		
HIICH_11	✓	✓			✓	✓	
HIICH_12		✓	✓		✓	✓	

Table 3. Mapping among proposed heuristics and usability constructs

VALIDATION

This section present Validation stage which encompassed testing of proposed heuristics. A controlled experiment is carried out by 48 professionals with background in mobile gaming, development and evaluation experience (1-12 years).

Control Experiment

A control experiment was designed to compare HIICH with general Heuristics (Nielsen's heuristics). This experiment was carried out using between-subjects design with 48 participants having the computing and game development & evaluation background. This methodology is more externally valid as compared to within-subjects design. Between-subjects design also removes results variation caused by Ordering Effect that normally occurs while using within-subjects design. A pilot study with 5 participants was initially conducted and the experiment's protocol, and briefing for participants was finalized based on observations made during the pilot study. During the controlled experiment, participants were randomly assigned one of control or treatment group with blinding technique. All participants were qualified for the experiment because they were familiar with different genres of games and had a background in smartphone game development, gaming, software quality and software engineering.

Experiment Protocol and Apparatus

The experiment protocol included a briefing about experiment's purpose and how to participate in the experiment. A single Android device, Samsung S4 Mini having a screen size of 4.3" and Android API level 4.4 was used with a pre-installed game.

Initially, smartphone games that involved intensive use of virtual controller or a set of controls, were shortlisted from Google Play Store's listings. These games belonged to complex interaction genres like Role Playing Games, Third Person Shooters and First Person Shooters.

Based on criterions of hyper-intense game plays, heavy user interaction during game plays and total number of downloads from Play Store; a total of three games were shortlisted namely; *Brothers in Arms*, *Shadow Fight 2* and *Metal Soldiers*.

A total of 48 evaluators took part in experiment. As endorsed in (Ali, 2022) an adequate number of participants in heuristic evaluation can be 20, hence; the sample size of 48 is sufficient

for this evaluation. Among the 48 respondents, 27 were male (56.25%) and 21 were female (43.75%). The ages of participants ranged from 18 to 35 years. A total of 13 participants were between the age of 18-23 (27.08%), 30 participants (62.5%) had age range of 24-29 and 5 participants (10.42%) were between the age of 30 and 35 years. Table 1 represents *gender*, *age groups* and other demographic information in both *control* and *treatment* group.

After the pilot study, the experiment began with a formal briefing regarding protocols. The individual assessment is carried out with each participant and each participant was compensated for their time. The game Metal Soldiers is used for heuristic evaluation in landscape view. We noted down each participant's name, age, gender, gaming experience and evaluation time duration. Each participant played the game for a few minutes to get acquainted with the game and then evaluated the game controls against each heuristic. All usability issues identified by the evaluator were noted down with a reference to relevant heuristic.

The controlled variables of the experiment included *a particular game* to be evaluated, *Hardware device*, and *Gaming experience* of evaluators. Participants were selected with at least 4 years gaming experience on smartphones and (or) smartphone game development & evaluation experiences of at least one year. The uncontrolled variables of the experiment included the Environmental factors, the Psychological states of participants and Time of the day.

Table 4. Demographic information of participants in Control Experiment

Heuristics Set	**Participants**	**Gender**		**Age (18-23)**	**Age (24-29)**	**Age (30-35)**
		Male	**Female**			
Nielson	24	11	13	5	16	3
HIICH	24	16	08	8	14	2
Total	**48**	**27**	**21**	**13(27.08%)**	**30(62.5%)**	**3 (10.42%)**

5.1.Hypothesis Testing, Data Analysis and Results:

The data collected from the control experiment is analyzed for significant usability problems.

$\boldsymbol{\mu}$ is the mean of the number of usability problems found with *HIICH*, and $\boldsymbol{\mu'}$ be the mean of the number of usability problems found using Nielsen's heuristics. We tested the null hypothesis $\boldsymbol{H_0}$: $\boldsymbol{\mu < \mu'}$ against the alternative hypothesis $\boldsymbol{H_a}$: $\boldsymbol{\mu > \mu'}$.

$$\boldsymbol{H_0 : \mu < \mu'}$$
$$\boldsymbol{H_a : \mu > \mu'}$$

Null Hypothesis ($\boldsymbol{H_0}$): The number of usability problems found by HIICH heuristics is less than the number of usability problems found by Nielsen's heuristics.

Alternative Hypothesis ($\boldsymbol{H_a}$): The number of usability problems found by HIICH heuristics is greater than the number of usability problems found by Nielsen's heuristics.

We applied hypothesis testing and found that the **p = 0.043765** at significance level **α = 0.05**. Hence null hypothesis can be rejected based on these results. We conclude that *HIICH* identified more usability relevant issues in hyper-intense smartphone games as compared to Nielson's heuristics. The number of usability problems and time taken by control and treatment groups are presented in following graphs:

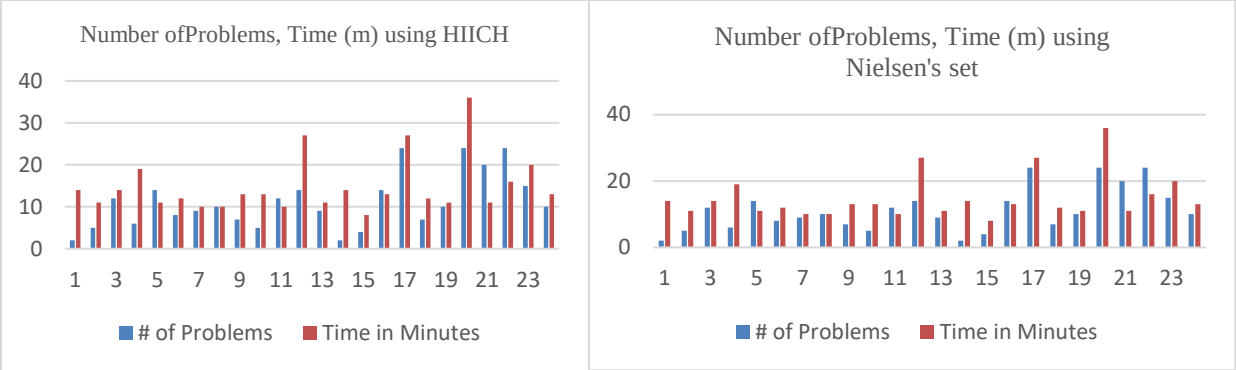

Fig. 15. Number of Usability problems uncovered by each participant along with time taken in minutes (m) using HIICH and Nielsen's set

The results discussed in this section and liaison of each proposed heuristic with usability constructs as presented in next section depict that proposed heuristics set *HIICH* will have impact in usability evaluations of RPS/TPS/RPGs genre in smartphone.

CONCLUSION

Smartphone mobile games pose many usability challenges owing to limited display size, playability constraints, and touch screen as primary input medium. Among these problems, interaction is a significant problem as complex games genres lack tactile feedback while using touch screen as input medium and standardization of input controls. This leads to various problems like inefficient screen space utilization, focusing and finding relevant controls, number of controls exceeding player's muscle memory, and unsuitable positioning of controls. These problems hinder game usability and user experience. Given methods of usability evaluation do not fully address or identify problems in such interfaces, especially controls in the case of complex and interaction-heavy games including First Person Shooters, Third Person Shooters, Role Playing Games and Action Games.

In order to address the aforementioned gap, we developed a set of 12 heuristics (HIICH) that assist in devising virtual controllers, enhancing playability and gaming experience. HIICH proved to uncovering usability issues at earlier stages and designing of input controls for complex / hyper-intense interaction genres. They are developed using an industry oriented approach in which multiple versions of virtual controller were initially designed and analyzed. Following six such iterations of design-develop-analysis we devised initial 12 heuristics. Proposed heuristics (HIICH) are evaluated both qualitatively and quantitatively. Firstly, qualitative analysis is done with industry experts to establish that the proposed heuristics are understandable, clear and consistent. Secondly, quantitative analysis compares proposed heuristic set with traditional/general Nielson heuristics. The results are statistically significant and clearly indicate that proposed heuristic set (HIICH) identify more problem related to interaction, on-screen controls. Based on the results, liaison of proposed heuristic set with usability constructs, we believe that HIICH is effective in uncovering usability issues in hyper-intense genre and can enormously impact usability studies, scientific community and industry in this context.

This research has certain limitations in terms of the confounding variables in control experiment including time, environment and psychological states of participants. Various future work areas can encompass implications and feasibility study of proposed heuristics in hyper-casual and simple genres of games. Another research direction is to investigate the influences of proposed heuristics (HIICH) on the decisions like gameplay, game design, game architecture and game mechanics.

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