Analyzing the Impact of Digitality and AI on HCI: Four Dimensions of Intelligent Digitality That Afford Innovative Designs

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Abstract - **Interactive games on the Internet often reflect aspects of 'serious' behavior and attitude found in the real and virtual worlds. They can be used to analyze how digitality may be designed to attain positive individual and social impact. Consider a game such as Wordle and think about how different it is from a printed word puzzle, and moreover, think about how even more different you can make it by adding more digitality in the game's form and the way it is played. This paper analyzes the distinct, albeit interrelated, dimensions in which intelligent digitality can innovate the product, the process, the agency and the environment of human-computer interaction. We build on previous HCI research and metaphors to provide a framework for incorporating digitality, especially AI, to produce innovative designs, demonstrating these ideas with the (imaginative) design of Wordle.**

Keywords – **digitality; HCI design; AI**

I. INTRODUCTION

Online behavior has become pervasive in our lives to the extent that we cannot ignore it in understanding human behavior and attitude online and offline. The distinct core of online behavior is the digitality than enables new behaviors it and impacts the human-computer interaction (HCI). While there are numerous studies on how elements of digitality, such as media richness, affect behavior, designers need a systematic approach to identify the potential innovations to HCI that digitality affords. Furthermore, in light of the growing pervasiveness of AI in online behavior, the potency of 'smart' (intelligent) digitality should be emphasized in innovating human-machine interaction.

This paper proposes a four-dimensional framework that identifies innovative functionality and usability afforded by digitality. Additional functionality, however, may bring higher complexity to the HCI, which underscores the roles of usability and flow in design but also plays a role in the allocation of tasks and responsibilities between human and AI-based agents. The framework, therefore, is also meant to assess complexity on each dimension and on the combination of dimensions.

Games are good for analyzing discretionary online behaviors, their antecedents and their effects [1]. This paper uses the online game Wordle to conceptualize the dimensions of the technology's impact on behavior, with special attention to the potential contribution of AI on each of the dimension. The analysis highlights several aspects that determine the potential of digitality to innovate designs and determine their resulting complexity. Furthermore, games underscore the hedonistic expectations of users that determine intentions to play the game and the user's experience with the game [2].

Wordle (https://www.nytimes.com/games/wordle) is a popular game, albeit a very specific type of online games, very different from video games. It is a puzzle type of game that has grown very popular in the past year to become a daily practice for millions of users round the world. The game has been translated to several languages, and has been studied in several domains, e.g., [3], [4].

Players can play the game only once a day. The player has six attempts to guess the correct five-letter word of the day. In each attempt, after considering all previous attempts, the player offers a legal candidate word. The candidate word is checked and the player receives the following feedback: each of the five letters is painted in black (to designate a letter that does not appear in the correct word), yellow (to designate a letter that appears in the correct word but in a different position), or green (to designate a letter that appears in the right position of the correct word). After receiving the feedback, the player proceeds to the next attempt. When the correct word is found, the player is congratulated according the number of attempts made (e.g., on the sixth attempt the feedback is 'phew'). Indeed, special attention will be given to the role of feedback. If the six attempts are exhausted before the correct word is identified, the player is notified of the correct word. In both cases, the new score is recorded and added to the player's history, which can easily be shared with others.

II. FOUR DIMENSIONS

We use this game to demonstrate four dimensions in which digitality can affect the way the game is played: product, process, agency and environment. These dimensions correspond to four questions about the game, namely, 1) what is the form (structure) of the game, 2) what is the process of playing the game, 3) who is

playing the game, and 4) who and what surrounds the player playing the game.

A. *Product*

For the first dimension, product, we ask what is the form and what is the functionality of the digital product. Potentially, the digital product can be very different from the non-digital product due to additional forms and functions afforded by digitality. Asking what in Wordle (the digital product) would not be feasible in a similar (non-digital) printed puzzle, demonstrates some of the digital characteristics in play. In Fig. 1, the screen has two parts: the upper part is a 5*6 matrix (columns for five letters and rows for six attempts), and the lower part is a keyboard presentation of the letters (QWERTY style) to show the accumulative feedback across attempts per letter.

Several aspects of digitality are relevant to the design of the form and functionality of the product such as interactivity, connectivity, channel capacity and adaptivity. We use the first two attributes to demonstrate how to consider digitality in the product.

Interactivity is an obvious digital characteristic that affords feedback [5]. The feedback is at the level of a single character, at the level of a word after each attempt, and at the level of a game after the correct word is found or after six failed attempts. The first type of feedback is instant feedback when typing a single character in a cell (e.g., a character that is not an English letter). A second feedback generated after each attempt consists of word level feedback shown in the upper part of the screen (Fig. 1), and additionally, the feedback is aggregated across attempts and shown at the level of a letter in the lower part. A third form of feedback is performance (outcome) feedback provided at the end of the game, as shown in Fig. 2. The performance statistics calculated by aggregating past games from previous days substantially change the non-digital game.

Feedback changes the process of playing the game (as explained in the next section) but it also changes the intention to use the game. In hedonic systems, perceived enjoyment and anticipated psychological wellbeing are as influential as perceived usefulness and ease of use in determining intentions to use [2,6,7]. Players become accustomed (if not addicted) to seeing their performance scores (Fig 2) to the extent they will not play if they cannot see their scores, much like joggers who will not jog unless they have their smart watches. (Wordle shows past scores only on your regular device.)

Connectivity is another digital characteristic critical for innovating HCI [8]. It affords links and relationships with others that are infeasible in the non-digital games. In particular, the easy ability to share results invites interactions with friends through social media. The additional functionality enabled by connectivity changes substantially the product, as does the feedback, affecting the user's perceived enjoyment or value, and, as a result, motivation to play.

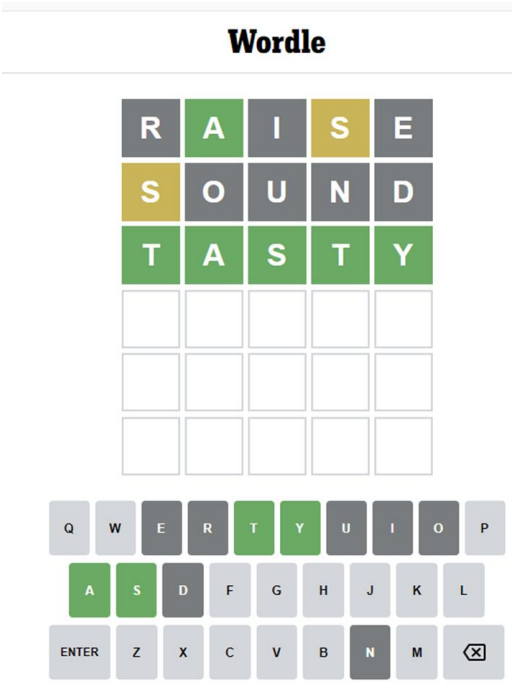

Figure 1. On the left, the word of the day 'Tasty' is guessed on the third attempt. On the right, six attempts failed to guess. Green is a letter in the word in its correct position, a Yellow letter is included in the word but is not in its correct position and Black letters are not in the word

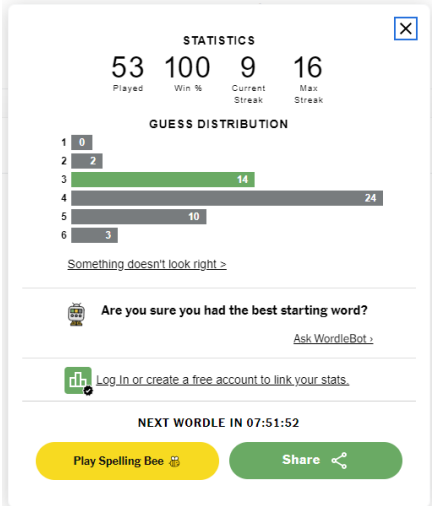

Figure 2. Additional functions in the digital product are the performance statistics and ability to share

B. *Process*

For the second dimension, process, we ask what is the user's process of using the product to achieve some goal. In the case of Wordle, what is the process of playing the game? One way of describing the process is to break it down into several steps such as deciding on a strategy, executing the strategy, studying the feedback, and revisiting the selected strategy and either continuing to execute it or revising the strategy and then executing it. Thus playing Wordle can be seen as following up to six iterations in a cycle of strategy-execution-feedback. For example, a strategy may consist of using the first two

attempts to find all or most of the vowels that appear or do not appear in the correct word and accordingly suggesting words that maximize the reduction of uncertainty (possible words given prior attempts). In executing the strategy, the first attempt could begin with a word that includes vowels, and according to the feedback continue with a second word of different vowels (see first two attempts in Fig. 1).

In the game represented in Fig. 3, the player revisited the strategy, assuming that most of the vowels had been identified so that there was no need to use the second attempt to identify further vowels. Accordingly, the second attempt began guessing the correct word. The third attempt failed to choose a word that minimized uncertainty, and resulted in a failed game (the correct word 'TASTY' is shown after six attempts).

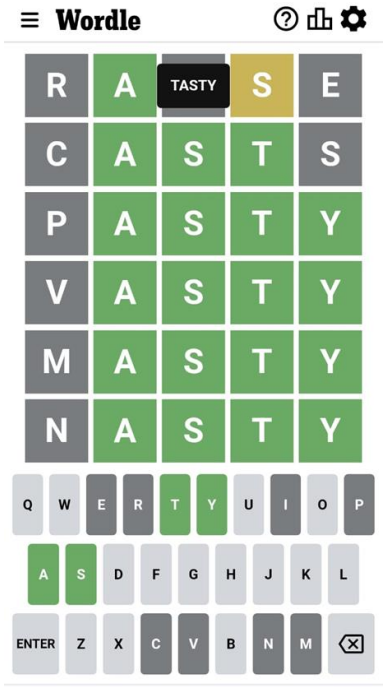

Figure 4. Inappropriate execution of a strategy resulting in a failed game

A comprehensive analysis of how digitality affects the process when it involves HCI must address the allocation of tasks between the human and the machine as explained in the next section on agency. Nevertheless, we can begin the analysis by ignoring for now which agent performs the tasks. The tasks in the strategy described above clearly rely on feedback afforded by digitality, primarily on the feedback at the level of a word after each attempt. More on feedback in the next section.

Actual behavior does not always follow the planned strategy-execute-feedback cycle flawlessly. Intelligent agents are expected to deal effectively with unplanned events or erroneous implementation of strategies. Some players request tips how to progress when strategy execution becomes too difficult. The three daily tips generated automatically for the correct word 'TASTY' were the following: 1) This word is an adjective; 2) It is used to describe food that has a pleasant, distinct flavor, and 3) It features a 'T'.

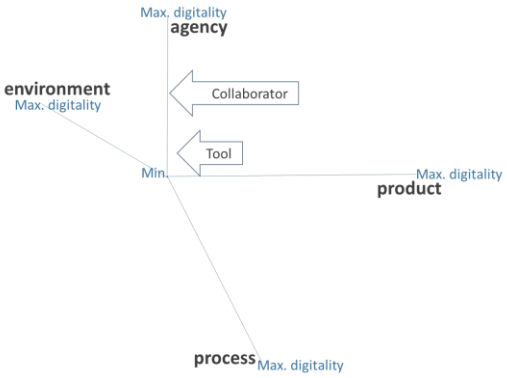

Figure 3. Four dimensions to incorporate digitality

C. *Agency*

A third dimension on which digitality affects HCI is agency [9]. For agency, we ask who governs, initiates, controls and bears the responsibility for the process and its sub-processes. Agency can be characterized on a continuum according to the latitude of decision making granted to the agent, e.g., [10].

In the case of Wordle, complete human autonomy is when the player has complete control over the process and sub-processes so that the player alone initiates and takes charge of all actions, even though execution of the player's orders may be executed by the machine. An autonomous machine is one that acts as its own agent. An autonomous game would be one that plays and displays the results when the game is over. In between these extreme cases are many combinations of human-machine configurations [11], often referred to as 'Keep the Human in the Loop' [12]. These configurations call for a shift away from the metaphor of computer as tool to a metaphor of collaboration between human and machine.

Under the collaboration metaphor too, human autonomy is seen as an important value in the design of HCI [13]. Indeed, in games, enjoyment and human autonomy should be design goals [14]. Nevertheless, the human-machine collaboration configuration introduces several complications that need to be addressed in their design. Collaboration assumes task allocation and intelligible communication between human and machine [11]. Smart digitality can enable or support both allocation of tasks requiring intelligence to the machine and intelligible communication between human and machine. For instance, a possible division of labor could be the player setting a strategy of first identifying which vowels appear in the correct word and communicating the message to the machine, and consequently, the machine suggesting the best words to implement the strategy. In such a division of labor, the player's sense of autonomy would not necessarily decrease because the higher level decision remains with the human [15].

A more complex collaboration would be to adapt the machine's algorithm to the human priority on which of the word's five positions to concentrate. For example, say the player wants to resolve positions 4 and 5, and asks the

machine to do so. Most machine algorithms for solving Wordle operate at the level of reducing uncertainty for the entire word, e.g., [16]. The incompatibility between the methods would require challenging algorithms to integrate the two and enable effective communication.

D. Environment

For the fourth dimension, environment or context, we ask who and what surrounds the user using the system. In the case of Wordle, in what virtual environment is the game played and what agents are part of the environment that interact or perhaps compete with the player, e.g., avatars that offer tips when asked.

Say the game is played in a virtual world, in which the player, represented by a similar looking avatar, can buy tips from other avatars dressed various experts. Thus an element of bargaining can add to the game's challenges.

Fig 4. sums up the four dimensions, product, process, agency and environment, that represent the opportunities to incorporate digitality in the design of HCI.

III. SMART FEEDBACK AND ADAPTIVITY

Feedback that utilizes AI ('smart feedback') can adapt its content and timing according to the player's state, skills and style, as well as to the game situation, e.g., the number of attempts already made. For instance, if the player is risk aversive, tips or suggested words can be tailored to be more conservative relative to suggestions compatible with an 'I'm feeling lucky' mood and ready to make a wild bet.

Adapting (tailoring) tips to the particular player and game situation is another example of smart responses. The three daily tips mentioned above, could be tailored to the first few attempts. For example, after the first two according to the history of attempts. The third tip "it features a 'T'." would be relevant after the first two attempts in Fig. 1 but not after the first two attempts in Fig. 3. The tips could additionally be tailored to the player. For example, the first tip ('… is an adjective') would fit a person who generally does not use adjectives. Moreover, if the machine is given privileges to decide when to provide a tip, it could detect signs of a user facing complexity, e.g., an unexpected pause, errors in writing a candidate word, or obviously redundant attempts that bring no new information. Thus based on a smart analysis of both past behavior and current situation game, the feedback or help can be adapted to the user and the game situation in terms of content and timing.

Adaptation that relies on intelligence is relevant to each and all four dimensions. For example, when an AI-based agent selects a strategy, it may (unlike the human strategy described above) select a sequence of candidate words that consistently and sequentially reduce uncertainty (as noted above in [16]). The feedback to the agent will be adapted accordingly. Furthermore, agency itself may change dynamically according to the results.

IV. COMPLEXITY

Fig. 4 specifies the opportunities for digitalization in HCI, but the four dimensions can also serve to assess the complexity of the human-computer interaction introduced into the new design. Firstly, digitality affords new functionality that almost always brings with it new complexity on the relevant dimension, and secondly, the interrelationship between the dimensions results in a combined effect that may further increase the complexity of the HCI.

Recently, a new version of Wordle has quadrupled it into a game called Quordle, greatly increasing the complexity of playing the game. In Quordle, the player has nine attempts to guess correctly *four* daily five-letter words simultaneously. The screen shown in Fig. 4 is divided into four matrices, each showing the history of attempts for one of the four correct words ('WRYLY' 'APPLE' 'SCOUR' 'CLUNG'). Accordingly, a matrix has five columns and nine rows. As in Wordle, the player offers a candidate word (In Fig. 4 the first candidate word is 'RAISE'), which is applied to all four matrices. This expansion would be practically infeasible in a non-digital version. The increased complexity on the product dimension is clearly visible.

Part of Quordle's additional complexity compared with Wordle (with a single matrix for a single correct word) is the need to manage attention between four correct words and the respective matrices. Consider the challenge in thinking of a candidate word so as to progress according to the feedback on previous attempts towards one correct word versus four correct words simultaneously. The players must manage their attention shifts from one matrix to another, recalling their thoughts about the previous matrices. Moreover, consider the complexity of reading the integrated feedback on a common keyboard (not shown in Fig. 5). The increased complexity compared with the original Wordle is the result of higher digitality on the dimension of the product (the four matrices) and on the dimension of the process (the attention and comprehension of the integrated feedback).

The complexity of the human-computer interaction created by the additional functionality afforded by digitality is due not only to complexity on each dimension but also to that generated by the combination of interrelated dimensions. For instance, the higher decision-making latitude of AI-based agents may require better coordination between processes. In Wordle, the differences in human and artificial strategies may require extra coordination and mutual understanding if the machine works at the level of a whole word and the human is interested in a candidate word to resolve a question about vowels at the end of the word.

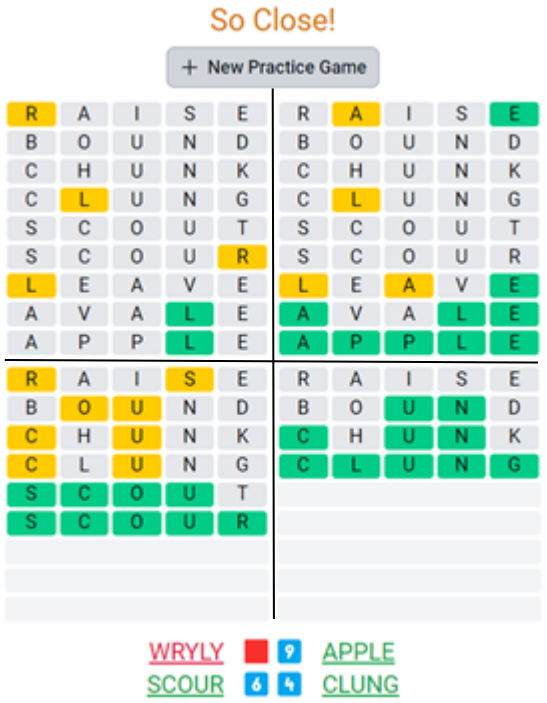

Figure 5. . Quordle with four words to guess simultaneously is highly complex

CONCLUSION

The four dimensions shown in Fig. 4 direct the designer's attention to opportunities that leverage digitality to innovate the design of HCI. Furthermore, taking feedback as one of the most impactful attributes of digitality, we show how AI in particular can leverage the capacity of digitality to innovate by adapting the content and timing of feedback to the user and the game situation. With added functionality afforded by smart digitality comes, however, added complexity, which can be reduced and managed, partly by adapting to the user's needs and preferences and by adjusting agency. Hence, the need to use the framework to consider at once both the potential impact of digitality and it consequent complexity.

This work can be seen as a first step towards a more general framework for leveraging digitality in the design of HCI. It took an individual perspective of a user and a machine that should be expanded to collective use of multiple agents. The framework should also be extended to incorporate specific procedures to identify possible contributions of digitality to each dimension. For example, specifying in advance likely attributes of digitality (e.g., interactivity, connectivity, capacity and adaptivity) that affect each dimension. More generally, the framework can be expanded by taking two perspectives: HCI and AI. For example, the HCI perspective considers both complexity and perceived complexity as two separate factors. In the analysis of Wordle, perceived complexity would be expected to affect the user's perceived enjoyment but also decisions of agency. The AI perspective for example, should consider the algorithmic implications of considering responsibility alongside authority when tasks are delegated to AI-based agents. Such extensions and expansions of the framework will hopefully emerge as the framework is put to use.

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