Tweetris: A Study of Whole-Body Interaction During a Public Art Event

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ABSTRACT

We explore whole-body interaction with *Tweetris*, a game where two players competitively race to form Tetris shapes (tetrominos) with their body. We debuted Tweetris at an all-night, public art event, collecting 6000 winning body shapes made by more than 270 players. Tweetris employs a novel form of interaction cue we call a *discretized silhouette:* the mapping from physical *continuous* input is *discretized* to create a virtual body representation. Discretization creates an interesting set of properties: notably, players have a great deal of flexibility in how they create a given shape with their body. We classify and analyze successful player strategies as design input for whole body interaction, and present results showing how small differences in environment impacted player behaviour. We argue that our approach to eliciting and analyzing interaction in Tweetris has general utility to researchers and designers and we formalize it as the *LoFi* (Low-Fidelity) *Elicitation Protocol.*

Author Keywords

Whole-body interaction, silhouette, public, art, video game

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

In Whole-Body Interaction (WBI), there are many ways to map the physical body to a system representation. One common approach is to use a raw, continuous *silhouette* [20,35,38], and another is to infer skeletal positions to map to an *avatar* [22,23,37]. With both approaches, the user interacts with the system by adopting specific poses or actions. While it is possible to require more or less accuracy in adopting the correct pose, a specific body configuration is typically imposed on the user.

In Tweetris (Figure 1), we explore the *discretized silhouette*, a down-sampling of the raw silhouette given by any body-detection sensor. While this may seem undesirable at first, studies investigating WBI controllers suggest that reducing the constraints imposed on the user encourages exploration of whole body interaction strategies [25,34]. Using the discretized silhouette, we suggest the shape the user is required to make without directing how the body is to be used to make the shape. In other words, the discretized silhouette allows for a variety of body configurations for the same shape. We argue that such flexibility has benefits for players, designers and researchers. For players, this can lead to more enjoyable and expressive gameplay. For designers and researchers, this flexibility—essentially a reduction of constraint—is an opportunity to observe and characterize natural WBI patterns.

Figure 1. Two players playing Tweetris in the back of a van.

We conducted our study of Tweetris during an art event, featuring engaging, novel interactive experiences, in a configuration that encouraged audience participation and casual engagement. We contrast our observations with our experiences exhibiting Tweetris later in other public contexts. There are a growing number of studies that investigate the effect of the interface's environment on WBI behavior [4,18,21,25,34,28,29], and varying environment is an important way to assess the generalizability of results in WBI studies. In this paper we argue that the discretized silhouette is a valuable tool when seeking to uncover environmental impacts.

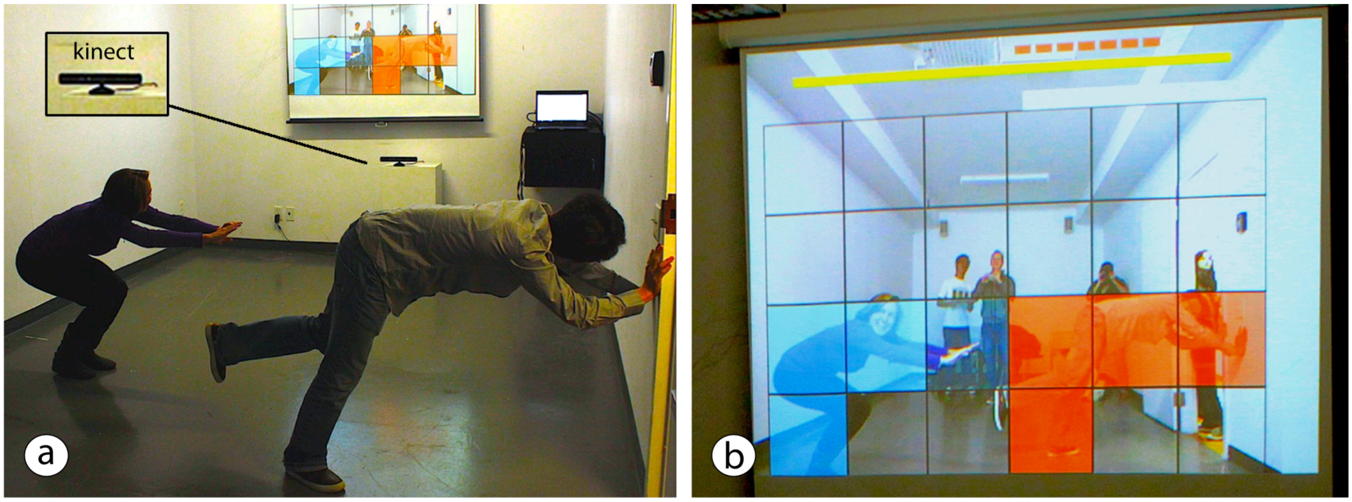

Figure 2. Two players attempting to match the same tetromino: (a) the view from behind the players and (b) a close-up of the Tweetris shape-matching interface as the players would see it. The right player's tetromino (red) is fully occupied, and a progress bar (in white, difficult to see) is increasing across the top. The right player will win if he manages to hold his position until the progress bar finishes. The left player (blue) has filled 3 out of 4 of her squares; her rightmost square is not filled, and is thus a lighter shade of blue. Note that the right player is using the wall as support.

The main contribution of this exploratory work is the implementation, analysis and formalization of a new WBI technique. The *discretized silhouette* stands in contrast to other digital body representations in its flexibility of user behaviour. We provide an analysis of WBI behaviour during a public art event, including a classification of interaction styles, a consideration of the environmental factors that impacted behaviour, and a comparison with other events.

In our analysis we observe that the discretization of the continuous silhouette is just one example of *reduction of fidelity* in the present interaction medium. Tweetris illustrates the utility of this in WBI (as suggested by previous studies [25]), but we believe it may also be usefully applied to other interaction mediums. We reflect on our research approach and develop it into an instrument—the *LoFi Elicitation Protocol*—as a means to examine an interactive medium by repeatedly eliciting interaction signs with low physical constraints and without imposed semantics.

TWEETRIS

We developed Tweetris as an interactive art exhibit for 2011 Nuit Blanche event in Toronto [33] Tweetris' design goal was to create an engaging experience that explored public play. At its core is the shape-matching game, where two players race to match their body's shape to a *tetromino,* from the game Tetris, i.e. ■, ■, ■, ■, ■, ■, and ▌. Tweetris' gameplay was partly inspired by a segment called *Brain Wall* on a Japanese TV show [36].

Figure 2 shows the experience of Tweetris from the shape-matchers' perspective. The interface presents the players with a real-time mirrored video of themselves, overlaid with a 6-wide by 4-high grid, colour-coded based on player presence. The silhouette of the player, overlaid on the down-sampled grid, represents *discretization* of the player's silhouette that conveniently maps to tetrominos.

Each player occupied a 3 by 4 grid, where each square in the grid had a binary state. This reduces the information contained in the body posture down to 12 bits per player.

Each square is translucent and colour-coded depending on its state: red (right player) and blue (left player) indicate a square belonging to the current shape to be matched, using a darker shade when the square is successfully occupied. A square that is not part of the goal shape, yet occupied, turns purple (not shown in Figure 2). Players must occupy the four grid squares for the given shape and no more, and hold that position for 1.5s while a white progress bar goes across the screen on top. If neither player makes the goal shape before a 10s countdown, a new random shape is displayed.

Tweetris uses a Microsoft Kinect [23] as its input device. The Kinect depth frame tags each pixel with a player id indicating the presence of a player. For a player to "occupy" a grid square in Tweetris, 30% of pixels in that square must have a non-zero player id. Tweetris uses the colour frame of the Kinect as feedback to the players. We used a Kinect instead of a 2D tracking approach, as the Kinect is more robust to volatile backgrounds and lighting conditions and we were more familiar with Kinect development.

Gameplay was "public" in different ways. A live audience, composed of potential and recent players, watched and encouraged current players, creating a social, performative space. Whoever made the correct shape fastest had their picture taken and uploaded to a Twitter account (players were informed of this before play). These player snapshots became playable in a second game: our custom online game of Tetris, where the pieces are overlaid with images of winners from the shape-matching game. A running instance of this game was broadcasted on a public display during the event.

BACKGROUND

Tweetris explores of a novel form of WBI, the discretized silhouette, leading to a wide diversity of player-produced interaction signs (in our case, whole-body configurations). In this section, we cover the different interaction styles seen in WBI, protocols used in research to elicit interaction signs, the influence of semantics and constraints on interaction, and examinations of interaction in public.

Whole-body Interaction Styles

There have been two major approaches to representing the user's body in WBI: *avatars* and *silhouettes*.

Avatars rely on accurate estimation of the user's skeleton. Real-time skeletal tracking became commercially viable with the Microsoft Kinect and many Kinect applications utilize avatars [23]. Marquadt et al.'s Super Mirror [22] teaches ballet movements by cueing players to go through a series of prescribed skeletal positions step-by-step. Freeman et al. have explored the effect of avatar representations using whole or partial skeletons [12].

Silhouettes are 2-dimensional outlines of the user's body. Krueger's early instance of WBI, VIDEOPLACE [20], uses silhouettes, and so does much following work [35,38]. Silhouettes can suggest the user adopt a particular posture: this is seen in the segment *Brain Wall* on a Japanese game show [36], and appears in the Kinect game *Hole in the Wall* [23]. Silhouettes also appear in multitouch tabletop work, both to suggest a specific hand posture [10], and, similar to our work, to cue the users to fill in an abstract shape [5]. Note that our discretized silhouette is a novel, intentional downsampling of a conventional silhouette.

Oulasvirta et al., while using motion capture, provide a metric for information capacity of full-body movements, though they examine movements and not static poses. They find relatively high values for dancing motions (208 to 584 bits per second), as compared to Tweetris' downsampling to 12 bits per player per posture.

Elicitation Protocols

We define *elicitation protocols* as procedures that are primarily concerned with eliciting novel interaction signs. They do so to help design application-agnostic interaction techniques in a chosen interaction medium, i.e. a method of communicating between the computer and the user. They primarily differ in terms of how they do (or do not) simulate the semantics of the hypothetical system.

Wizard-of-Oz (WoOz) is the most well known protocol: researchers give participants a series of high-level tasks to accomplish in a particular application domain and interaction medium. Signs and referents may or may not known in advance by participants. Participants repeatedly attempt signs while the wizard attempts to interpret the signs. The interplay between signs from the participant and responses from the wizard yields knowledge about the application domain and the interaction medium.

In the User-Defined Gestures (UDG) protocol [40], a system shows participants a series of before-and-after states of a system, and asks them to propose a corresponding sign. In Wobbrock et al.'s work [40], there are no high-level tasks, and a sign is elicited for each referent only once. While this aids in constraining the results for easier analysis, there is no observation of one participant experimenting with different signs over the course of a high-level task. Also, researchers must determine a set of referents *a priori*.

In Rewarding the Original (RtO), Williamson and Murray-Smith sought to elicit novel movements in the domain of hand motion. They attached an inertial measurement unit to the dominant hand of study participants, and used a reinforcement mechanism to encourage them to find "original" motion primitives [39]. In this case, there were no tasks or referents at all. The protocol focuses on finding novel movements, as opposed to "natural" or common ones.

Semantics

An interface metaphor, such as "desktop" or "folder" gives users a sense for how a system functions. When interacting with a system, users apply cognitive *image schema*, patterns and relations developed through interaction with the world during their lifetime (e.g., up-down, big-small). Hurtienne et al. [17] argue that an interaction sign is an instance of a cognitive image schema associated through a primary metaphor with a particular target domain (e.g. the image-schema of UP-DOWN, applied through the metaphor "up is more, down is less" appears in many volume controls). Unsurprisingly, the signs, schema and metaphors used in WBI are major topics of research [1,4,19].

Guiding interaction via signs and metaphor constrains what we can learn about the limits and potential of new mediums of interaction. Since the WoOz and UDG elicitation protocols offer high-level tasks and referents respectively, they bias the mind of the user towards particular metaphors when eliciting signs, which could limit their capacity to explore the whole space of an interaction medium. RtO offers interactive feedback to encourage participants to create more novel signs, but even this requires an *a priori* definition of "novelty" in the medium.

The discretized silhouette in Tweetris represents an instance of a stimulus with low inherent meaning, or semantics. This is in contrast to task-based semantics, or rich semantics as explored by Bianchi-Berthouze and others [4] in WBI.

Constraints

Systems that incorporate body motion or posture require some degree of precision from the user. A higher degree of precision may reduce false positives, but imposes greater constraints on the user. Nijhar et al. found in a study of "exertion" game controllers (in this case, a Nintendo Wii) that increased requirements on movement precision led to a richer and more realistic experience for players [25]. By contrast, Ibister et al. [18] illustrate how flexibility in WBI may encourage the emergence of flow [6] (a feeling of optimal performance and mastery), and Reilly shows how reducing postural constraints can yield more consistent behavior for certain pointing interactions [30].

It is clear that more research is required in order to understand the relationship between constraint, flow, and performance in WBI. The discretized silhouette provides a means to observe emergent patterns in WBI before imposing constraints that may prove awkward or otherwise counterproductive.

Environmental Impact

Physiological, cognitive, emotional and social environments all affect user behaviour. *Immersion*, *Engagement* and *Experience* are similar terms used to describe how focused the player or user is [4, 8,28,32]. Fogtmann loosely defined *movability* as whether the body can move freely based on physiological restrictions [8].

There is a growing interest in studying the effects of environment and social presence on WBI behaviour. Multiple influences, such as the physical environment or social presence combine to influence selection of postures and non-essential behaviour during WBI [2,3,21]. Public, social environments are much less controlled than lab environments, but allow researchers to observe behaviour and attitudes not possible in a lab [14,18,37]. In addition, differences on a perceptual or cognitive level can emerge when moving interaction techniques from lab environments into public ones [30]. Even simulated social interaction can yield interesting behaviour [29]. We exhibited Tweetris at multiple public events and observed variations in players' response to the game. Here, we report on the study on one specific exhibit, and contrast it with other subsequent experiences.

EVENT STUDIED

Art Event and Participants

Nuit Blanche 2011 is a free, public event presenting contemporary art in public spaces over a 12-hour period from sunset to sunrise [33]. City spaces become temporary exhibitions with a wide diversity of experiences. Attendees represent a wide range of the population: individual adults, families and even groups of friends. Event-goers wander around—with or without a specific planned path—looking for opportunities to step in and engage in the various installations that happen to be close-by.

Physical Set-Up

Our set-up consisted of two simultaneous installations: one in a parked van on a city street, another in a dedicated room in a gallery space (Figure 3). In the van, we placed several pads loosely on the floor (Figure 1).

Collected Data

If a participant won by holding the shape for the required 1.5 seconds before their opponent did, a snapshot of them was taken and saved. Before they participated in the game, we ensured visitors understood that snapshots of their full body were posted publicly on Twitter if they won. As participants agreed to have that data in the public domain, we used all photos posted on Twitter in our analysis.

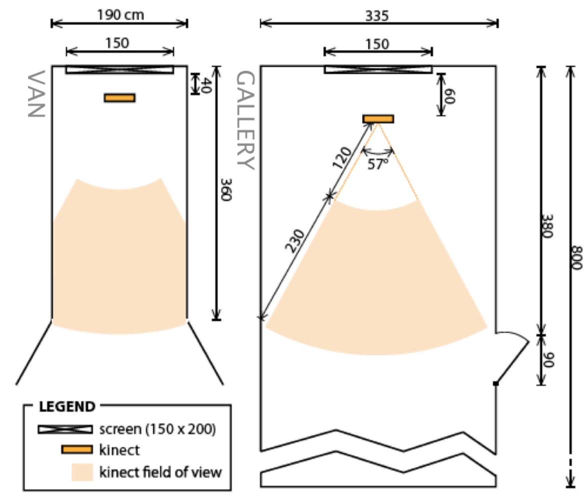

Figure 3. The two Tweetris installations.

We collected 3424 shapes in the van and 2954 at the gallery, from over 270 participants. For each snapshot of a successful shape, we recorded: the installation location (van or gallery), participant location (left or right), the timestamp, and the tetromino shape and rotation.

Manual Coding

To capture low-level player behaviour for analysis, the authors performed the following coding on snapshots of the successfully made shapes at the van location:

Body rotation: the player's torso rotation relative to the game display (left, right, forward).

Body posture: the basic posture used by players, either sitting, lying down, standing, squatting, kneeling, or "crouching" (kneeling on one leg).

Limb location: for each of a tetromino's four squares, the body parts contained within them (left/right hand, left/right elbow, left/right knee, left/right foot, head, hips). Despite skeletal position data being available in the Kinect SDK, we found that this is not entirely reliable, especially with players' unusual body shapes.

Hand availability: for each hand, whether it was available (able to move freely) or not (e.g. used for balance)

Hand behaviour: whether hands were both clenched, both relaxed, both outstretched, or different.

There was substantial agreement between the researchers on a ten snapshot test set, after which each author encoded about 360 snapshots, for a total of 1438 (some discarded because of poor lighting or other issues).

To compare the differences in environmental constraints introduced by the two experimental locations, we also coded *Body Rotation* and *Body Posture* at the gallery location, for a further 1812 shapes. As coding was extremely time consuming and we had ample data from our van location for analysis that did not consider impact of location, we did not do the full coding at the gallery location.

OBSERVATIONS

Tweetris was popular, and the line-up occasionally exceeded 10 minutes. While some individuals appeared to be seriously concentrating while playing, the majority smiled and laughed. Many ignored the time limit to make a fun shape, which is reflected in the creativity and variety of approaches we observed. As Tweetris has no textual instructions, audience members (especially those who had recently played) would call out instructions to players. Other audience members would laugh or applause the players' actions.

Having exhibited Tweetris in a number of other locations since the art event study, we attribute the positive response to a combination of game design *and* social context. While enthusiastically embraced at the art event, play was less dynamic and creative at an educational event and an interactive arts conference, where players seemed to enjoy themselves less and appeared more self-conscious.

RESULTS

Figure 4 shows the proportion of successful shapes for each tetromino, in both the van and gallery settings. The figure illustrates that the overall level of difficulty in making the various shapes remained consistent across location.

Body Rotation

More than twice as many shapes were successfully made turned away from the wall than toward it (351 vs. 145, a factor of 2.42). A binomial test for one proportion shows that this difference is significant ($z = 9.25$, $p < 0.0001$). There was no significant difference between the left and right side in the number of shapes successfully made overall. However, for some tetrominos, there was a pronounced difference between the sides (Figure 5). With these shapes, the players tended to twist their upper body to the left or right, and the differences in proportions shown correspond with moving away from the wall rather than toward it.

As the gallery space was 1.45 m wider than the van, it gives more room between each player and the wall. We hypothesized that the impact of the wall found in the van would be less pronounced than in the gallery. As Figure 5 illustrates, the differences in proportions remain, but are less pronounced than in the van setting.

In the gallery, more successful left-rotated shapes were recorded, i.e. when the player was facing away from onlookers at the gallery door, on both the right (181/325, $z=2.052$, $p=0.02$) and left (168/282, $z=3.216$, $p=0.001$) player sides.

Body Posture Transitions

Standing, squatting or crouching permitted rapid changes in body posture. Sitting, lying and kneeling require more effort to move into a new posture, and so we expected that these postures would be more stable compared to the others.

In our own experience playing the game, we found kneeling was an effective high-level posture, as it was comfortable and allowed all shapes to be made, including , with stretching. Thus, we expect to see a high degree of consistency in the use of kneeling, versus the other postures.

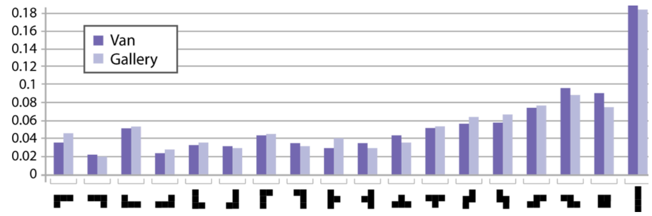

Figure 4. Proportion of successful shapes by tetronimo. Participants were about equally likely to successfully make each kind of tetronimo in both the van and gallery settings.

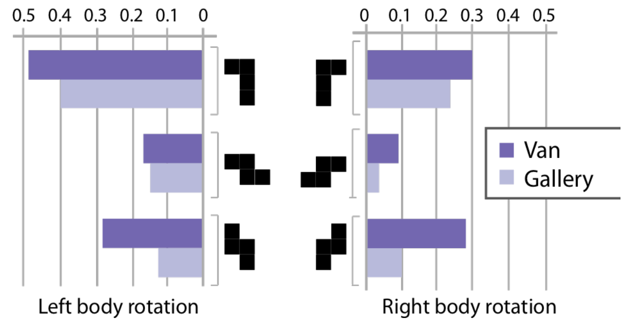

Figure 5. Proportional differences in successful shapes suited for body rotation. Greater proportions of successful shapes were made when rotated left, and shapes when rotated right. The proportional differences are consistently more pronounced in the more cramped van setting than in the gallery. Differences are significant in both settings for every shape except .

As we only analyze winning snapshots and did not impose a minimum playing time, we cannot directly observe body posture transitions. We analyzed the number of times each player used each basic posture. In the van, players were kneeling in 35% of shapes, with the remaining split between standing (25%), squatting (20%), crouching (15%), and sitting or lying down (5%). In our analysis of long sequences of individual players in the van, we did identify series where players remained kneeling, as expected. This contrasts with the gallery, where only 7% of shapes had the player kneeling. Most were standing (40%), with the remainder crouching (31%), squatting (18%) and sitting or lying down (4%). We observed that body movements seemed more subdued in the gallery - many shapes were completed standing or almost standing.

Hand Behaviour

Coding. For every snapshot, we classified the behaviour of both hands into one of the categories *clenched, relaxed, extended,* or *different.* Clenched hands were fists. Extended hands had fingers outstretched; we did not distinguish if the fingers were together or not. In 27% of images we could not accurately classify both hands.

Results. The most common behaviour was extended (59%), followed by relaxed (24%) and clenched (14%). Both hands tended to have the same shape, even if they were not in the same grid square; hands were only different 12% of the time. Interestingly, hands were often extended when it was not necessary to complete the shape. While an extended hand does take up more pixels than a fist, it does not make significant difference unless the palm of the hand is turned to face the camera; players rarely did this.

The proportion of clenched, relaxed and extended hands varied significantly from shape to shape in interesting ways. Extended hands were the most common in every shape except , where they accounted for 7% of shapes, with the remainder clenched (49%), relaxed (43%) or different (%1).

Different hands were less common in symmetrical shapes: (%1), (3%) and (1%). The exception is (21%), but this mostly occurred when the player was turned left or right, with one hand extended and the other relaxed or clenched near his or her crotch. Elsewhere hands in spatially asymmetric positions tended to be different as well, as with and (both 29%).

As we noted, the most common occurrence of clenching was with (49%), followed by , (41%). and and (both 15%). Occurrence in other shapes is negligible. In many cases with , participants would clench hands near their face when having them relaxed by their side would have been suitable.

The high amount of clenching in (41%) was an anomaly. had 0 cases of clenches out of 54 shapes. While we cannot be sure why clenching is so common in , we note that the players' arms need to reach slightly more to form the shape - perhaps this notion of "reaching" influenced players' hand behaviour.

Strategies

We define a *strategy* as the whole-body plan behind a shape formed by a player. We did a secondary coding to capture players' strategies, clustering alike strategies by tetromino. During the first coding, we observed typical behaviours (e.g. hands outstretched to fill extremal squares). In most cases, we can relate a pose to *strategy* that guides where to place the limbs. We empirically determined pose strategies for each tetromino and used them to classify the images.

Figures 6 and 7 (at end) show an overview of the pose strategies for each tetromino (note that we consider horizontal reflections of tetrominos to be in the same category). We identify a strategy as a "main" strategy if it appears in more than 20% of the winning snapshots for each tetromino; this gives us one or two main pose strategies for each tetromino.

Overall, we found that main winning strategies tended to require the least movement from one tetromino to the next. These were often poses where limbs are stretched out to reach the extremal squares, rather than contorting the torso to match the shape. Moving the arms, even for reaching far extremals, seems to be a preferred and successful strategy overall (see for example Figure 7K2-4).

Qualitative feedback

During our exhibit, some attendees were invited to fill out a questionnaire after playing to the game. However, the response rate was low (~60 players) as it was difficult to administer during the live event. Most respondents reported high satisfaction and enjoyment but we did not collect particularly useful data in relation to interaction characteristics.

DISCUSSION

The unique nature of our investigation yielded useful general implications about the WBI medium. The discretized silhouette allowed us to make several observations on the effects of constraints and semantics in body configurations involving shape matching. Our study, and the subsequent exhibitions of Tweetris at other public events, also permitted us to push the exploration beyond the traditional lab setting. Our observations confirm the importance to understand the impact of the environment on users' behaviour.

Constraints

The discretized silhouette design emerged as we were mapping from body shapes to Tetris pieces. However, unwittingly, we were giving players a great deal of freedom to perform the match for any shape. Players' creative freedom to form a shape in Tweetris was a major part of their enjoyment. "Easy" shapes, such as , implied an obvious posture (see Figure 6A). For "difficult" shapes, such as and , Tweetris' lack of suggested posture encouraged players to experiment by trial-and-error to find a suitable posture. The set of tetrominos under 90-degree rotations covers all well-connected arrangements of four squares, so we can be confident that we have a broad coverage of coarse body configurations possible in WBI.

If we were to show a more continuous silhouette, it may have implied that there was one or a few "correct" ways to make the shape. This would be appropriate if we were looking to study known interaction techniques. We believe that silhouette discretization allows for interaction techniques to emerge from the users. Using our process, we discovered common pose strategies and behaviour that could serve, for example, to inform the design of hand behaviour in concert with whole-body behaviour.

Semantics

While we attempted to reduce the opportunity for embodied metaphor [1] in the design of Tweetris, we see indications that players expressed an internalization of the shape. Hands were often engaged as part of a whole body "expression" of the shape being made. Typical examples are in Figure 7G5-7, where the right hand overlaps the head from the camera's perspective, and is therefore unnecessary. See also Figure 6A4-7, where participants formed by bringing hands together on top of the head. In "stretched" shapes, such as or , the hands tended to be more extended; in "squished" shapes, such as , the hands tended to be more clenched. With and especially, as players experience these similar shapes repeatedly, we suspect their hand behaviour conforms to the sensation of longer or shorter arms, which is why has a higher frequency of clenching.

The above observations support both the notion of interaction as a connection to a cognitive image schema (i.e. stretched-squished) [17], as well as the whole-body engagement hypothesis [5]. The explicit or implicit engagement of the hands that we observe in shape-making cautions against designs that presume hands will be free to perform gestures that are independent of a gesture expressed by the body. The implication here is that the number of degrees of freedom available in the body is not equal to the number of enumerable joints; if the body strikes a pose, the semantics of that pose engages the entire body.

Tweetris repeatedly cues players to create interaction signs without any semantics attached to them, or link to a particular interface command as a referent. Many elicitation protocols (see Background) use specific referents to cue users. Tweetris was free from such restrictions, and while individual postures made by players exhibited low-level image schema, they were not self-conscious of higher-level semantics of their actions. By avoiding imposed semantics, we could sample the "medium" of WBI, free of an application, or *a priori* ideas from the designers. This approach may allow observations of semantics inherent to the particular interaction medium. We believe that this can serve as a basis for designing effective and appropriate WBI.

Environmental Impacts

While it is widely admitted that environment has an impact on users' response (this is why controlled studies follow a well-framed, constrained set up), the environment, as a factor, remains only anecdotic in WBI [25]. Yet, the observations and conclusions from such controlled studies are often generalized to the widest range, the impact of social or physical variation in the environment being rarely discussed. We argue that one should expect a potentially high variation depending on the physical or social situation, and that this is even more relevant to WBI, which by nature is inextricably connected to physical environment [1,11,30].

To our surprise, through Tweetris we observed a strong difference in player behaviour between environments. If not given the opportunity of repeating the exhibition, we would have kept our first impression that Tweetris is popular, fun, and highly engaging, regardless of the situation. We encourage designers to reconsider the secondary role of the environment factor in experimental protocol.

Our results show that even in spaces cleared of furniture, qualities such as floor surface and layout can significantly impact WBI. The increased proportion of kneeling in the van compared to the gallery may be due the physical environment (the discomfort of a harder floor), or the social environment: (the audience's closer proximity to the players in the gallery). The decreased number of successful shapes made when facing the gallery door suggests that the players were distracted by eye contact with onlookers, or sought to avoid it. In more informal settings, there was a social reward for novelty, as people creating shapes were given laughter or applause as feedback. There are certainly performative interaction factors at play here, as the players are made aware of their own movements (by their live image in the game) as well as others watching them [16].

Snibbe et al. recommends using silhouettes instead of colour video as feedback, as they have observed people experiencing discomfort with a video representation of themselves [35]. However, Tweetris is very fast-paced so players may not have time to become critical of their own images. As Harrison and Dourish have noted [13], environments are more than just physical layouts and need to be understood within larger social contexts. We understand that just because a condition seems irrelevant or of a secondary importance to the researcher, does not mean it will not affect the subject under study. We suggest that it is crucial to also do research out of the traditional lab setting, where such discoveries can be made.

PROPOSING THE LOFI PROTOCOL

With Tweetris instructing players to make specific shapes without constraining them how, we effectively discovered a new way to elicit instances of expression in the WBI medium. The degree of creativity and variation in shape-making went beyond expectations and would have been difficult to anticipate. We now formalize this idea into a study protocol that aims to explore the range of expression in any medium, while reducing the bias introduced by semantics and task constraints. The *LoFi* (Low Fidelity) *Elicitation Protocol* does this by offering a series of low-fidelity signs and suggesting that the participant produce a sign to match them. We describe three features of a *LoFi* protocol study:

R1: Semantics-free. The interface should offer as little opportunity as possible for semantic or metaphorical interpretations. There should be no explicit referents or tasks.

R2: Constraint-reduced. The fidelity of the cued signs should be low enough so that there is little constraint on how the participant forms them.

R3: Coverage of the Medium. The procedure and low-fidelity signs must cover a broad set of possibilities in the expression medium, both simple and complex.

For illustration, take the medium of tabletop interaction. In the *LoFi* protocol, a researcher would show a participant a touch contact trace, and then encourage them to mimic it. If the trace was a single arc, we would expect to participants to use the index finger of their dominant hand. However, what would participants do in the case of multiple traces? We might reduce the cue fidelity further by using numbered points and telling participants to "connect-the-dots".

To assess the impact of environment on subject behaviour in a medium, one could run the same LoFi protocol study in multiple environments, and examine the variation in elicited interaction signs, as we did with Tweetris.

CONCLUSION

We created a new form of WBI, the *discretized silhouette*, during our development of Tweetris. We analyzed players' behaviour during a public art event and found the discretized silhouette led to a diversity of interesting behaviour with potential implications for WBI design. First, we found the image schema of "fill", "fit inside" and "cover", by observing the correlations between hand and whole-body behaviour. Second, whole-body interaction uses the *whole body* – if unconstrained, the hands will often expressively mimic the shape that the whole body is forming. Third, physical objects and social presence in the environment affect how users orient themselves, even if they are not in danger of physically colliding with them. We recommend that WBI systems have an awareness of the constraints and tendencies of the current stable posture of the user, and adjust widgets and targets correspondingly. We also formalized our method of evaluation into the LoFi protocol, which may be useful to study other interaction mediums.

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REFERENCES

1. Antle, A.N., Corness, G., and Bevans, A. Springboard: Designing Image Schema Based Embodied Interaction for an Abstract Domain. *Whole Body Interaction.* Springer, 2011, ch. 2, 7–18.
2. Bardy, B. Postural coordination dynamics in standing. *Coordination dynamics: Issues and trends 1* 2004, 103–121.
3. Bardy, B., Oullier,O., Bootsma,R., and Stoffregen,T. Dynamics of human postural transitions. *Journal of Experimental Psychology: Human Perception and Performance; 28,* 3 (2002), 499.
4. Bianchi-Berthouze, N. (2012). Understanding the role of body movement in player engagement. Human-Computer interaction, 28, 1-36.
5. Cao, X., Wilson, A., Balakrishnan, R., Hinckley, K., and Hudson, S. ShapeTouch: Leveraging Contact Shape on Interactive Surfaces. In Proc. of IEEE TABLETOP 2008. p. 139-146.
6. Csikszentmihalyi, M. *Flow: the psychology of optimal experience,* 1st ed. ed. Harper & Row, 1990.
7. Fischer, M. Estimating reachability: Whole body engagement or postural stability? *Human movement science 19,* 3 (2000), 297–318.
8. Fogtmann, M. H., Fritsch, J., and Kortbek, K. J. Kinesthetic interaction: revealing the bodily potential in interaction design. In Proc. of ACM OZCHI 2008, 89–96.
9. Fox, R. Socializing around arcade technology. Communuications of *the ACM 40* (August 1997), 26–28.
10. Freeman, D., Benko, H., Morris, M.R., and Wigdor,D., ShadowGuides: visualizations for in-situ learning of multi-touch and whole-hand gestures. In Proc. of ACM ITS 2009 165-172.
11. Freeman, D., Chevalier, F., Westecott, E., Duffield, K., Hartman, K. and Reilly, D. 2012 Tweetris: play with me. In *ACM TEI 2012*.
12. Freeman, D., Hilliges, O., Sellen, A., O'Hara, K., Izadi, S. and Wood, K. The Role of Physical Controllers in Motion Video Gaming. ACM DIS 2012.
13. Harrison, S., and Dourish, P. Re-place-ing space: the roles of place and space in collaborative systems. In ACM CSCW 1996, 67–76.
14. Hinrichs, U. and Carpendale, S. Gestures in the wild: study multi-touch gesture sequences on interactive tabletop exhibits. In Proc. of ACM CHI 2011. 3023 - 3032.
15. Holland, S., Wilkie, K., Bouwer, A., Dalgleish, M., and Mulholland, P. Whole body interaction in abstract domains. In *Whole Body Interaction,* 2011, ch 3, 19–34.
16. Hornecker, E. and Burr, J. Getting a grip on tangible interaction: a framework on physical space and social interaction. In Proc. of ACM CHI 2006. 437 - 446.
17. Hurtienne, J., Stöíel, C., Sturm, C., Maus, A., Rötting, M., Langdon, P., and Clarkson, J. Physical gestures for abstract concepts: Inclusive design with primary metaphors. *Interacting with Computers 22,* 6 (Nov. 2010), 475–484.
18. Isbister, K. "Enabling social play: A framework for design and evaluation", In Evaluating User Experiences in Games: Concepts and Methods, R . Bernhaupt, ed. Springer, London, 2010.
19. Johnson, M. The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason. 1987. University of Chicago Press.
20. Krueger, M.W., Gionfriddo, T., and Hinrichsen, K. Videoplace an artificial reality. In Proc. of ACM CHI 1985, 35–40.
21. Lindley, S., Le Couteur, J., & Bianchi-Berthouze, N. Stirring up Experience through Movement in Game Play: Effects on Engagement and Social Behaviour. In Proc. of ACM CHI 2008, 511-514.
22. Marquardt, Z., Beira, J., Em, N., Paiva, I., and Kox, S. Super Mirror: a kinect interface for ballet dancers. In *ACM CHI EA 2012*.
23. Microsoft Xbox Kinect. http://www.xbox.com/en-US/kinect
24. Mueller, F., Agamanolis, S., Gibbs, M.R., Vetere, F.: Remote impact: shadowboxing over a distance. In ACM CHI EA 2008.
25. Nijhar, J., Bianchi-Berthouze, N., Boguslawski, G, "Does Movement Recognition Precision affect the Player Experience in Exertion Games?", (INTETAIN 2011), LNICST 78, 2012, pp. 73-82.
26. Oulasvirta, A., and Bergstrom-Lehtovirta, J. Ease of juggling: studying the effects of manual multitasking. In Proc. of ACM CHI 2011. 3103–3112.
27. Oulasvirta, A., Roos, T., Modig, A., Leppänen, L. Information Capacity of Full-Body Movements. In Proc of ACM CHI 2013.
28. Pasch, M., Bianchi-Berthouze, N., van Dijk, B., and Nijholt, A, "Movement-based Sports Video Games: Investigating Motivation and Gaming Experience", Entertainment Computing, vol. 9, 2, 2009, pp. 169-180.
29. Reidsma, D., Welbergen, H., van Poppe, R., Bos, P., Nijholt, A. Towards bi-directional dancing interaction. Harper, R., Rauterberg, M., Combetto, M. (eds.) ICEC 2006, Lecture Notes in Computer Science, LNCS 4161, Springer, 1–12.
30. Reilly, D. F. Reaching the same point: effects on consistency when pointing at objects in the physical environment without feedback. International Journal of Human-Computer Studies, 69(1-2):9-18, 2011.
31. Reilly, D.F., and Inkpen, K.M. White rooms and morphing don't mix: setting and the evaluation of visualization techniques. In Proc. of ACM CHI 2007. 111–120.
32. Savva, N., Scarinzi, A., Bianchi-Berthouze, N. (2012). Continuous recognition of player's affective body expression as dynamic quality of aesthetic experience. IEEE Transactions on Computational Intelligence and AI in Games 4(3), 199-212.
33. Scotiabank Nuit Blanche Toronto. http://www.scotiabanknuitblanche.ca/, Oct. 2011
34. Shoemaker, G., Tang, A., & Booth, K. S. (n.d.). Shadow Reaching: A New Perspective on Interaction for Large Wall Displays, In Proc. of ACM UIST 2007. 53-56.
35. Snibbe, S.S. and Raffle, H.S. Social immersive media: pursuing best practices for multi-user interactive camera/projector exhibits. In Proc. of ACM CHI 2009. 1447-1456.
36. *Tonneruzu no Minasan no Okage deshita*. Tonneruzu lounge website. http://www.tnlounge.net/
37. Walter, R., Bailly, G. and Müller, J. StrikeAPose: Revealing Mid-Air Gestures on Public Displays. In Proc. of ACM CHI 2013.
38. Warren, J. Unencumbered full body interaction in videogames. *Unpublished Master's Thesis, Parsons School of Design* (2003).
39. Williamson, J. and Murray-Smith, R. Rewarding the Original: Explorations in Joint User-Sensor Motion Spaces. In Proc. of ACM CHI 2012. 1717 - 1726.
40. Wobbrock, J.O., Morris, M.R., and Wilson, A.D. User-defined gestures for surface computing. In Proc. of ACM CHI 2009. 1083–1092.

Figure 6. Examples of shapes made by participants.

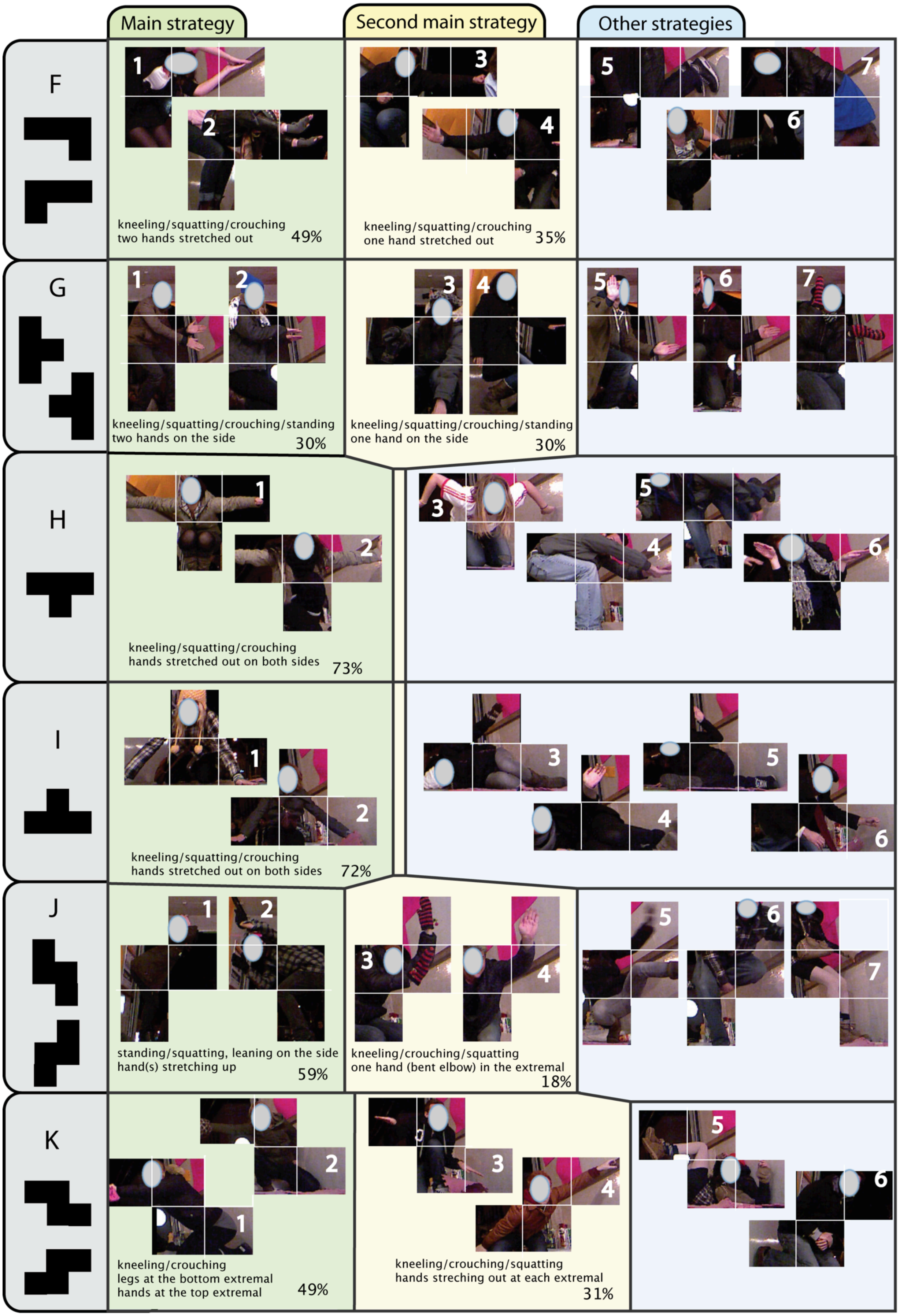

Figure 7. Examples of shapes made by participants.