Lasting Impression: Interaction With Embodied Puppet Leads to Changes in the Way People Draw Sketches

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Abstract

We have built an embodied puppet interface to explore the control and cognitive relations players establish with their virtual avatars. We are particularly interested in how these relations could be extended and what lasting effects occur. Here we report the results of a study that revealed that altering the mapping between the embodied puppet and virtual avatar led to changes in the way people sketch in the real world. Our results show that motor adaptations during the game carry over to real world activity. This effect could be extended to develop rehabilitation applications.

Keywords

Puppet, embodied interface, tangible user interface, virtual character, video game, common coding, body memory, sketching, expression, creativity

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces---*input devices and strategies, interaction styles*; J.4 [Social and Behavioral Sciences]: *Psychology*; J.5 [Arts and Humanities]: *Performing arts*. K.8 [Personal Computing]: *Games*.

Introduction

Our research involves building embodied interfaces, and investigating the control relation and the cognitive connection players create between their own bodies and the virtual bodies of the avatars they manipulate using these interfaces. This work is driven by recent results from cognitive neuroscience, showing that execution, perception, and imagination of movements share a common coding in the brain [3, 7, 8]. One effect of this common coding is that it allows people to recognize their own movements better than the movements of other people [4]. We are interested in this own-movement effect because, if it extends to interactions in the virtual world, it creates an efficient channel that allows players to make a more direct connection between their own physical movements and those of the virtual avatar. We have previously shown that this channel can be used to extend the space of imagined and perceived movements [5, 6]. Here, we report a study exploring how this channel may be used to transfer novel movement characteristics executed by the character on screen back to the player. This channel may be exploited to extend the space of executable actions in applied contexts, for example in the case of patients who have lost (some) control of one of their limbs as a result of a stroke [2].

To investigate this two-way channel of movement mapping, we have developed an embodied puppet interface that transfers a player's own body movements to a 3D virtual avatar in real-time. We have shown that this interface supports players' recognition of their own movements in the avatar [5]. Our system includes customized games in the virtual environment, which allow the player to execute and perceive movements in the virtual world that are not commonly executed in the real world. Using one such game, we showed that the embodied mapping between player and avatar provided by the puppet interface leads to performance advantages and improvements in the players' ability to do a spatial cognition task such as mental rotation [6]. The mental rotation result supports previous work that shows lasting cognitive and information processing changes from playing video games (e.g., [9]).

To further explore such after-effects, we investigated whether interaction with the puppet interface could lead to effects in unrelated tasks executed after such interaction. To this end, we altered the mappings between the puppet and the avatar (by exaggerating or diminishing the avatar's movements in response to the movements of the puppet) and tested whether this led to changes in the way people draw sketches after the virtual interaction (e.g. changing speed or pressure of drawing).

This question explores how (far) the control relation between the puppet and the player could be extended, by looking at whether these adaptations last beyond the virtual interaction, and if so, what kind of effects they have. The following sections provide an overview of the puppet interface, the experimental setup, and results. We conclude with a discussion of the results and future directions.

Background

Puppet Interface

The puppet interface is a hybrid full-body puppet that is strapped to the player's body, and controlled by the player's arms, legs, and body (see Figure 1). This approach provides a high level of articulation and expressiveness in movement [5]. The puppet consists of 10 joints at the knees, hips, waist, shoulders, elbows and neck, allowing us to capture a range of movement data. It is built out of wooden "bone" pieces that are connected across the joints using potentiometers (one or two depending on the number of axes of rotation of the joint). The puppet's feet attach to the player's knees, its head attaches to their neck, and its midsection attaches to their waist. The player uses their hands to control the arms of the puppet. The puppet is easily controlled by both the hand and full-body movements of the player and faithfully transfers the player's movements to their virtual avatar. For details about the system design and development, see [5, 6].

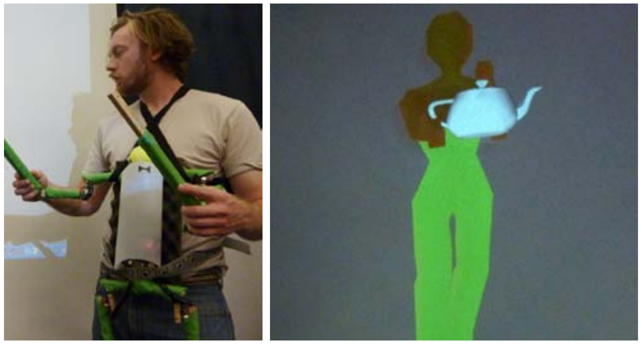

figure 1. Player interacting with the embodied puppet interface (left); player's game avatar (right).

Game Environment

Movement data from the puppet is wirelessly transmitted to the Unity 3D engine, allowing the physical puppet interface to steer a virtual puppet in real-time (Figure 1). In Unity, we can develop games that manipulate the connection between the puppet and avatar. Altering this connection allows us to investigate whether changes in the movement of an avatar that retains the player's own movement patterns transfer back to the player and affect the their performance in cognitive or expressive tasks.

For our previous studies, we developed a virtual contact game in which virtual objects (teapots) appear in the space around the player's avatar. The player must manipulate the puppet to make their avatar touch the objects with its arms or legs [6]. The goal is to touch as many objects as possible in the time provided. For our current study, we modified this game to support three mapping conditions between the movements executed by the player/puppet and those of the avatar: Normal, Fast, and Slow. In the Normal condition, the avatar moves at the same speed as the puppet/player. In the Fast condition, the avatar moves twice as fast as the puppet/player, causing the movements of the avatar to appear exaggerated relative to the movements made by the player. In the Slow condition, the avatar moves at half the speed of the puppet/player, causing the movements of the avatar to appear diminished relative to the movements made by the player. The Fast and Slow conditions were developed by multiplying the displacement (potentiometer) values by 2 and 0.5, respectively, causing the joints of the virtual character to rotate in a faster or slower speed. The camera perspective showed the avatar facing the player, like in a mirror.

Background

The experiment tested whether playing the virtual contact game using our puppet interface in the Fast and Slow conditions changes the way participants engage in a subsequent unrelated task – sketching. To index these changes, we assessed the characteristics (speed and pressure) of drawing before and after experience with the virtual contact game. The drawings were done using a WACOM digital tablet and pen.

Procedure

Participants were first asked to draw two sketches (Baseline). After the Baseline drawings, participants played the virtual contact game for 10 minutes with a normal real-to-virtual movement mapping (i.e. the avatar moved at the same speed as the participant). The system tracked their proficiency (average intertouch time, i.e. time between two virtual object touches) during the last 3 minutes of gameplay. Next, participants repeated the drawing task (Experimental Phase 1). Participants then played the virtual contact game again. However, this time the avatar moved either with slower or faster responses in the 3D world (manipulated conditions, Slow and Fast) or with the same one-to-one (Normal) mapping. After 7 minutes of gameplay, the system began to track the player's intertouch times and gameplay was stopped when their previous level of proficiency was reached (but no sooner than 10 minutes, and no later than 15 minutes). Finally, participants once again completed the drawing task (Experimental Phase 2).

The two drawings (a four-leaf clover and a smiley face) at Baseline and in each of the Phases were made using the BETS (Behavioral Traits from Sketches) system that was built in a previous research project [1]. BETS captures speed and pressure of drawings made using a WACOM digital tablet and pen (see Figure 2). Speed is captured in pixels per millisecond and the tablet outputs 1024 levels of pen tip pressure.

Participants were divided into three different groups that completed only one version of the mapping in Experimental Phase 2 (Normal, Fast, or Slow). The differences between the drawing characteristics at Baseline and after the different Phases provided our measure of the influence of the mapping in the game. The hypothesis was that, while the first play test (Experimental Phase 1) established a connection between the player and the avatar movements, different mappings between player movements and avatar movements in Experimental Phase 2 would lead to similar changes in the drawings (i.e., slower movements would lead to slower/lighter drawings and faster movements to faster/heavier drawings).

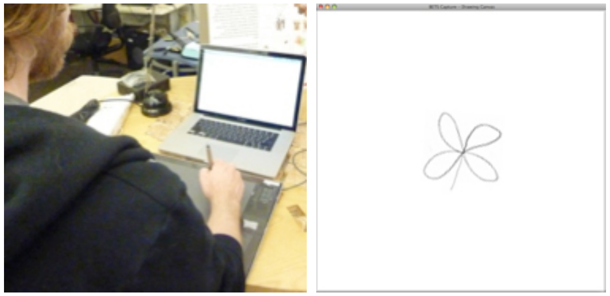

figure 2. Using the BETS system to draw a clover (left); screen shot of the clover drawn using BETS (right).

Subjects

There were 30 participants in the study, all over 18 years old. None had used the puppet interface before. On arrival, participants were randomly assigned to one of three experimental groups. Each group (10 participants) played the game under a different real-to-virtual mapping condition (i.e., Normal, Slow, or Fast).

Results

To assess the effects of the different mapping contexts on motor performance in the real world, the average pressure and speed on the Baseline (i.e., prior to game experience) trials were subtracted from the values obtained after Experimental Phase 1 and 2. These difference scores thus represent the change in performance that occurs as a function of normal (Phase 1) and altered (Phase 2) game experience. Before calculating the difference scores, the data were averaged across the two pictures as analyses across pictures did not reveal any theoretically-relevant effects. These difference scores were then submitted to separate 3 (Mapping Group: Normal, Fast, Slow) by 2 (Experimental Phase: 1, 2) mixed analysis of variance with Group as a between-subjects factor and Experimental Phase as a within-subjected factor. Alpha was set at 0.05.

Contrary to our hypothesis, the different mappings did not affect the speed of the drawing (*F*s<1.0). The mappings, however, did significantly influence the pressure the participants exerted on the drawing surface (see Figure 3). Specifically, post hoc analysis of the significant Group by Phase interaction, *F*(2, 27)=4.29, *p*<.05, revealed that there was a significant decrease in pressure in the performance of the group who executed the game in the Slow condition, *t*(9)=2.26, *p*=.05. Likewise, there was a trend towards an increase in pressure in the group that played in the Fast condition (did not reach statistical significance, *t*(9)=1.83, *p*<.11). It is important to note that the pressures from the group who performed in the Normal condition did not change, *t*(9)=0.40, *p*>.69. Overall, these data provide evidence that the way players adapted to the remapping led to carry-over effects for real-world movements.

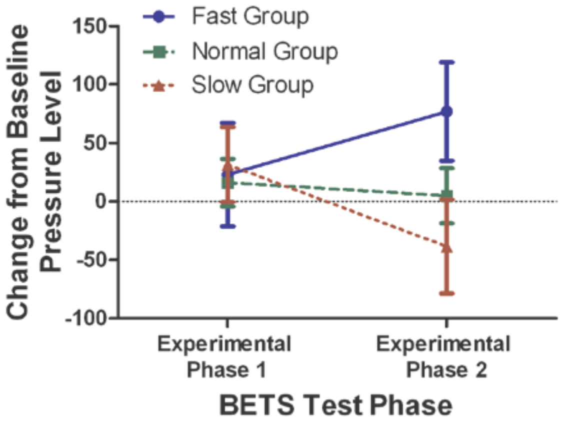

figure 3. Changes in pressure from baseline in the drawings made by participants in the three different mapping conditions: Normal, Slow, and Fast.

Discussion

The overall pattern of effects suggests that, contrary to our hypothesis, the interaction experience with the different mappings is not coded in a speed-to-speed fashion. Instead, a different mapping between the two tasks is visible: the speed experience in the puppet interaction translates into a pressure difference in the drawing task. Why? It could be that experiencing an unusual real-virtual speed mapping can lead to a discordance during the task and the subsequent after-effect is expressed through muscular force generation (which is clearly linked to action speed). With this in mind, it is interesting to note the direction of the carry-over effects – significantly less pressure following exposure to the Slow mapping and a non-significant trend to more pressure following exposure to the Fast mapping. It seems unclear why the after-effect would be in these directions - i.e., the group exposed to the Slow mapping reduced their pressure while drawing. This result may seem counterintuitive because the Slow condition leads to an experience akin to "swimming in molasses" where the feedback from your actions is that a given muscle contraction is not having the effect it typically does and that you have to "work harder" in real space to achieve the same displacement in virtual space. The usual response to such situations is to overdo your actions (as in typing many times when a character does not appear immediately on screen). However, the opposite occurred, with participants exerting less pressure after exposure to the Slow condition.

One possible explanation for this begins with a consideration of the relationship between force and speed and the mapping conditions. In the Slow condition, a normal (typical) amount of force translated into a relatively smaller amount of movement of the virtual character, forcing the participant to generate a relatively large amount of force to generate a normal amount of displacement in the virtual world. In returning to the real world, that relatively large amount of force would now result in a relatively large amount of displacement. Thus, in order to generate a "normal" displacement in the real world, the participant would have to decrease the absolute amount of force in comparison to what was just experienced in the virtual world. They had to decrease the amount of force needed to generate the same displacement and speed in the real world where the speed relation is once again 1:1. It is possible that the participants overcompensated for the amount of decrease required, resulting in an overall decrease in recorded force (pressure). The same could be suggested for the transfer in the Fast group, though the discordance may not have been as robust in the virtual world, leading to a less robust (and non-significant) negative transfer effect.

For interaction design, this indicates a more complex relationship between tangible interface performance and subsequent activity. During the embodied interaction, the system adapts to maintain control, but after the virtual task, the after-effects of this embodiment are not necessarily related to the adaptation in a 1:1 fashion, but self-(over)-regulated. The transition between embodied interaction and following real-world tasks (e.g. controlling the avatar and operating a selection menu) are continuously crossed in games, online collaboration worlds, or chat environments. The results indicate a necessary fine-tuning of interfaces to compensate for the detected after-effect.

Conclusion and Future Directions

The study presented in this paper provides preliminary evidence that altering the way in which the movements of an embodied puppet interface map onto the avatar can have carry-over effects to the player's subsequent movements in the real world. Specifically, we found that altering the speed at which the avatar moved in relation to the speed of input movements influenced the pressure participants exerted when drawing sketches immediately after the puppet interaction. Further studies could help to reveal the nature of these carry-over effects and could improve our understanding of the control relation between players and their avatars through embodied interfaces. We believe this understanding can benefit interface and game designers, as embodied interfaces become mainstream (e.g., in video games and multi-screen TV). Hybrid interfaces might confuse an interactor's mapping, and complicate the interaction at hand. If applied correctly, the effect could be used positively, particularly in the rehabilitation of patients with movement disorders. More broadly, our application of common coding theory to digital media design has provided an application focus to the embodied cognition approach in cognitive science, and also demonstrates a way in which common coding can provide a framework for designing novel computational media applications. Technically, incorporating physical feedback into the puppet device (e.g. using vibrating motors at the joints), the virtual avatar's movements could feed back into the physical device and stimulate player movements. This sort of enhancement could be useful for teaching certain movements (e.g. in a workflow) or in rehabilitation applications.

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