COLLABORATIVE WORK USING GIVE AND TAKE PASSING PROTOCOLS

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To effectively design computer simulations of shared environments, an understanding is needed of the basic informational requirements and underlying movement patterns generated by two people collaborating in these environments. Results from this study indicate that when passing objects in a natural environment, the fundamental movement patterns seen during simple grasping tasks are altered to accommodate the collaborative nature and social constraints of the task. When giving objects, although subjects reach further, they reach more quickly than when the objects are taken. This result may indicate a social consideration taken by the passer to move quickly and efficiently over a long distance to transfer the object to the receiver. Thus, the receiver does not have to travel as far or as fast to receive the given object. However, when objects are taken, passers move more slowly and lift the objects higher. This result may indicate that the passer times their movement so that they are not waiting at the end of their movement for the receiver to reach the target. Thus, although the result of the task is the same (the receiver obtains the object), the underlying movement patterns differ with the goal and social constraints of the movement. These results may be used to develop predictive algorithms when designing virtual and augmented environments. Future experiments will concentrate on the nature of visual and haptic information required for both the passer and receiver to effectively perform a passing task in an augmented environment.

INTRODUCTION

Collaborative activity is fundamental to human movement and social behavior. We collaborate with others in both our home and work environments in the course of daily life. Looking to the future, we may also collaborate with a co-located or remote co-worker via a virtual or augmented environment. In these environments, physical, augmented and virtual objects could be manipulated and shared using haptic, audio and graphic computer technologies. Before we can build effective “collaborative virtual environments” we must first understand the nature of the information needed for collaboration.

Studies have been conducted to understand human movements in natural (see MacKenzie & Iberall, 1994 for review) and in augmented environments (Graham & MacKenzie, 1996; Wang et al., 1998). As well, research has been conducted to understand the benefits of collaborative activities for effective work and learning (Inkpen et al., 1997; Suzuki & Kato, 1995). However, little is known about the underlying movement patterns generated when two people collaborate within a physical space. This information will be essential for modeling and optimizing the hardware and software requirements of virtual environments. Thus, the goal of this experiment is to gain an understanding of the fundamental movement patterns generated by two people as they perform a collaborative passing task in a natural environment.

METHOD

Participants

Sixteen, healthy, right-handed, human volunteers with normal or corrected to normal vision provided informed consent and participated in this study. Ethical approval from the Simon Fraser University Office of the Vice President, Research was obtained before testing began. Subjects were paid ten dollars for participation in the study.

Task

Participants performed a collaborative passing task. This task represents a basic collaborative activity where movement and communication are required of both performers for the task to be completed successfully. For each trial, one participant in the pair played the role of passer, while the second participant played the role of receiver. Using the right hand, the passer reached for, grasped and transported an object toward the receiver in either the give or take protocol. For the give protocol, the passer was instructed to grasp and lift the object and then “give” the object to their partner. The partner was instructed to receive the object with their right hand and replace it in the target position. For the take protocol, the passer was instructed to grasp and lift the object and then “take” the object to their partner. The partner was instructed to receive the object with their right hand and replace it in the target position. Although the result of both the give and take protocols is the same (i.e. the receiver obtains the object), the subtle difference between the give and take passing tasks allows us to assess the effects of task goal and social protocol on passing behavior.

At the beginning of each trial, the subjects sat facing each other across a table. They were asked to rest their right hands on the start position, which was in line with their right shoulders (see Figure 1). The object was located 18 cm in front of each starting position.

Each subject played the role of passer and receiver (2 conditions) and performed the task by giving and taking (2 protocols). A total of forty trials, with ten trials in each of the four conditions listed above, were performed.
Apparatus

Kinematic measurements of both the subject and object movement trajectories were collected using an OPTOTRAK 3-D motion analysis system (Northern Digital Inc., Waterloo, Canada) which monitored infrared emitting diodes (IREDs). IREDs were positioned on the right index fingers and thumbs of both subjects and a fifth IRED was positioned on the rectangular wooden block (6.8 cm X 3 cm X 3 cm). The camera sensed 3-D position data at 200 Hz and transferred it to a Sun workstation for later analyses. Copper contact plates were positioned on the two faces of the block which served as the grasping surfaces. Thin insulated wires were attached to the index fingers and thumbs of the two subjects. This caused a circuit to close when the copper plates positioned on the block were contacted. The contact signal was transferred to a personal computer by means of an A/D converter, which was time synchronized with the 3-D position data being measured from the IREDs.

Data Processing and Analysis

Each trial was divided into two phases. The timeline in Figure 2 illustrates the phases in a typical trial including the kinematic events that mark their start and end points.

Phase 1: This phase describes the kinematic events generated by the passer when transporting the object from the start location towards the receiver. This phase starts when the passer first contacts the object and ends when the receiver makes contact with the object.

The following dependent measures were used to describe Phase 1: movement time (MT), peak velocity (PV), time to peak velocity (TPV), time from peak velocity (TFPV), peak displacement in the forward direction (Ydisp), and peak displacement in the vertical direction (Zdisp).

Phase 2: This phase occurs while the receiver moves from the start position to make contact with the approaching object.

Phase 2 starts when the receiver first lifts their hand off the start position. Phase 2 ends when the receiver first touches the contact plate on the object. The following dependent measures were chosen to describe the kinematic events occurring in Phase 2: MT, PV, TPV, and TFPV. It was not necessary to repeat the Ydisp and Zdisp dependent measures for the receiver. Ydisp for the receiver can be calculated by subtracting the total forward displacement of the receiver from the Ydisp of the passer. The Zdisp of the receiver matches the Zdisp of the passer.

Each of the dependent measures for the two phases were submitted to univariate one way (protocol: give, take) repeated measures analyses of variance (ANOVAs). An a priori alpha level was set at $p < 0.05$.

RESULTS

Phase 1: Passer

Statistical analyses revealed a protocol main effect for MT ($F_{1,15}=5.0$, $p=0.04$). The passer spent significantly less time transporting the object to the receiver when using the give protocol than when using the take protocol. This shorter movement time for the give protocol was characterized by a higher peak velocity than for the take protocol ($F_{1,15}=6.3$, $p=0.02$). Figure 3 illustrates results for both movement time and peak velocity.

Figure 3: Phase 1. The passer transported the object longer when passing in the take protocol than in the give protocol. However, this longer movement time in the take protocol was characterized by a lower peak velocity.
The passer transported the object significantly further toward the receiver in the give protocol than in the take protocol \((F_{1,15}=73.8, p<0.01)\). However, the passer lifted the object higher in the take protocol than in the give protocol \((F_{1,15}=7.81, p=0.01)\). These results can be seen in figure 4.

Although subjects spent a similar amount of time reaching peak velocity for both the give and take protocols \((F_{1,15}=3.02, p=0.10)\) they spent a significantly longer time after peak velocity in the take protocol than in the give protocol. \((F_{1,15}=12.81, p<0.01)\). Figure 5 illustrates this result.

**DISCUSSION**

**Fundamental Movement Patterns**

Taken together, results for the passer and receiver give us some indication as to the fundamental movement patterns and underlying social interactions that occur during the performance of a collaborative task.

In this experiment, we found that when giving an object to a partner, people transport the object further toward their partner, and they take less time to make that movement than when...
the object is taken from them. This result is contrary to evi-
dence found in the motor control and human computer interac-
tion literature regarding the effects of target amplitude on
movement time (Fitts', 1954; MacKenzie et al., 1987; Graham
& MacKenzie, 1996). It has been shown that when reaching
to a further target, people take longer. However, we also
found that people reached a greater peak velocity when giving
the object than when the object was taken. Thus, for giving it
appears that people reached further in a shorter movement
time by significantly increasing the velocity of their movement.
These results indicate that the well documented
movement patterns produced in simple unimanual reaching and grasping
tasks (see MacKenzie & Iberall, 1994) are not produced when
objects are passed to partners. When two people are involved
in the prehensile movement, it is necessary to ensure that both
people have sufficient time to make their movements. How-
ever, in order to ensure that movements are made efficiently, it
may also be important to plan the movements so that no time
is wasted waiting for the other person. By speeding the giving
movement the passer may have been attempting to ensure that
the receiver did not have to wait for the object at the end of
the movement. Thus social protocol may be an important fac-
tor when movements are made between partners.

When the object was taken, the passer transported the
object higher than when giving the object. This may have oc-
curred because the passer was aware that the receiver would
need sufficient time to reach for the object. In the take proto-
col, the receiver had to travel much farther toward the target.
By lifting the object higher, the passer may have been trying to
avoid waiting for the receiver at the end of the movement.
Thus, although the result of both the giving and taking move-
ments are the same, the nature of the task is clearly different.
Both the passer and the receiver likely use information to an-
ticipate and alter their movement trajectories to accommodate
their partner and the goal of the task.

Previous research in motor control has shown that when a
grasping task is more complex, people spend more time decel-
erating toward the target than in less complex movements but
they spend relatively less time accelerating (Martinuik et al.,
1990). In this experiment, time from peak velocity was found
to be greater for both the passer and receiver in the take proto-
col. This result is somewhat puzzling. The give protocol re-
quires that the receiver intercept a quickly moving target,
while in the take protocol, the target should be relatively still
when the receiver contacts it. Thus, at least for the receiver,
the give protocol would appear to be a more complex task.
These results may have occurred due to timing constraints
when the object was given. It is possible that because of the
complex timing required in the give protocol, neither the
passer nor the receiver were able to anticipate what their part-
ner might do and slow their movements adequately. This
would result in greater force generation on the object when
passing in the give protocol. Perhaps, both subjects used their
partner’s action or the object as a mechanical stop when the
object was given, while in the take protocol, each partner in-
tentionally slowed their movement down using muscular force.
This hypothesis will be tested in future experiments.

Implications for Virtual and Augmented Environments

Currently, the realism within augmented and virtual envi-
rments is limited due to the inherent lag when using sensor
based information to draw graphics. With current technology,
it is impossible for any system to display graphics based on
movement with less than 1 frame of lag at 60 Hz. While this
time delay may appear to be non-significant, it is perceptible
by the human user. One possible solution to this problem is
to use data collected from human movement studies to math-
ematically model and predict upcoming movements. These
predictive algorithms must be based on our knowledge of
movement kinematics in various situations. To compute
these predictive algorithms we must first understand funda-
mental human movement patterns in a variety of simple and
complex situations. Experiments such as the one described
above will begin to build the databases of knowledge on hu-
man movement in collaborative settings.

Future Work

Having completed baseline tests of collaborative passing
in natural environments, we can now focus on collaboration
in augmented environments. The goal of future experiments in
the Virtual Hand Laboratory at Simon Fraser University
will be to manipulate the visual information available about
the passer and the object being passed. This experiment will
allow us to assess what the receiver must be able to see about
his/her partner and the object for effective collaboration. As
well, we intend to measure how force generation on aug-
mented objects is affected by a collaborative passing activity.

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