Title
Effect of combining the direction of three human-like objects on choice between two apertures

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 45(45)

Authors
Makino, Ryosaku
Kodama, Kentaro
Tomono, Takayuki
et al.

Publication Date
2023

Peer reviewed

Effect of combining the direction of three human-like objects on choice between two apertures

Ryosaku Makino(rmakino19@aoni.waseda.jp)
Faculty of Human Sciences, Waseda University
2-579-15 Mikajima Tokorozawa-shi Saitama, Japan

Kentaro Kodama(Kodama_k@tmu.ac.jp)
University Education Cetnter, Tokyo Metropolitan University
1−1 Minami-Osawa Hachioji-shi Tokyo, Japan

Takayuki Tomono (tomono@sgu.ac.jp)
Department of Psychology, Sapporo Gakuin University
5-1-1 Atsubetsu-chuo Atsubetsu-ku Sapporo-shi Hokkaido, Japan

Katsumi Watanabe (katz@waseda.jp)
Faculty of Science and Engineering, Waseda University
3-4-1 Okubo, Shinjuku-ku Tokyo, Japan

Abstract

Two experiments were conducted to investigate perceptual judg ment and choice of apertures in a virtual environment. In both experiments, we showed participants two apertures of the same width consisting of three human-like objects on a computer screen. In Experiment 1, participants were asked to judge which apertures they perceived to be wider. In Experiment 2, participants were asked to choose which apertures they preferred to pass through. We manipulated the face directions of the three human-like objects and analyzed participants' choice ratios. In Experiment 1, there was a significant difference in width perception in specific condition. In Experiment 2, there were significant differences in choice of aperture in all eight conditions. These results indicate that the combination of three human-like objects' directions affects the participant's aperture choice. Surprisingly, although two apertures were physically the same width, we found perceptual bias or illusion in choice between them under particular experimental conditions.

Keywords: aperture passing; human-like object; anisotropic structure; social affordance; F-formation.

Introduction

People pass through crowds daily and appropriately to avoid crashing into others and disturbing their actions . In this study, we conducted an experiment to clarify the perceptual bias in choice between two apertures (i.e., gaps) consisting of human-like objects.

Experiments have long been conducted on the behavior of passing through apertures in cognitive science, especially in ecological psychology . Warren and Whang (1987) conducted an experiment in which participants were presented with apertures of various widths and asked to determine the minimum width of the aperture that they could pass through without turning their shoulders. Studies on aperture crossing (Higuchi et al., 2004; Higuchi et al., 2011; Wagman & Taylor, 2005; Warren & Whang, 1987) indicate that the perception of the participants is based on an intrinsic body-scaled ratio (e.g., a ratio of aperture width to actor's shoulder width). These studies have focused mainly on situations comprising only one aperture. However, these individuals live in a cluttered environment and are likely to encounter situations consisting of more than one aperture. For example, a person will choose one of several apertures configured by others when moving during a standing party.

A subsequent question includes: What kind of aperture do people preferentially select when presented with multiple apertures? If there are merely multiple apertures, people will naturally select a wide aperture rather than a narrow aperture. In previous studies on aperture crossing, only a few experiments have been conducted asking participants to select one of multiple apertures to pass through. One of these experiments presented the participants with multiple apertures of different widths. Thereafter, the participants selected one of them, raced through it as fast as possible in a wheelchair, and selected a smallest passable aperture (Shaw et al., 1995). Hackney et al. (2018) also conducted an experiment in which multiple apertures were presented longitudinally, and all the apertures were passed through. These results revealed that the shortest path to pass through the last aperture was selected regardless of the position of the middle aperture.

These studies suggest that people are influenced by environmental characteristics when choosing from various apertures. However, people would need to consider both the physical aspects, such as the aperture width, and the social aspects (e.g., where the people in the aperture are facing, with whom they are talking, and how not to avoid disturbing them)

In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society*.

when passing through an aperture composed of people who appear in a standing party as in the previous example.

Kendon (1990) recorded and qualitatively analyzed in detail a standing party which found that it would be disturbing for a person to try passing through a space that others are using for some activity. Kendon (1990) also analyzed the behavior of people talking with each other and found that they overlapped each other's *transactional segment* to form a specific formation. Moreover, Kendon (1990) observed people in conversation and found that they established a specific formation (i.e., the *F-formation*) by overlapping each other's transactional segments.

Tomono et al. (2019) conducted experiments on how people can pass through an aperture between two people. Specifically, they examined the effects of the direction of two people in an aperture on the direction of passage (i.e., the angle of shoulder rotation, the trajectory, and walking speed when passing through the aperture). Consequently, the researchers reported a larger shoulder rotation angle when the two people constructing the aperture faced each other. The results of Tomono et al. (2019) suggest that it may be possible that people consider it more difficult to pass the condition in the face-to-face arrangement in which the F-formation is formed. In contrast, these findings also suggest that the condition is easy to pass in the back-to-back arrangement in which the F-formation is not formed. Thus, whether people are standing in a position where they appear to be communicating significantly affects who passes through the aperture.

We interpreted this study's findings to mean that passers may preferentially select an aperture in which people are not communicating with each other when passing through multiple apertures, rather than an aperture in which people are communicating with each other. The current study investigated which of two apertures consisting of people (i.e., human-like objects) with different directions is preferentially selected. Specifically, three types of arrangements were prepared when setting two objects: (1) "same-direction arrangement," in which the human-like objects are oriented in the same direction; (2) "face-to-face arrangement," where the human-objects face each other; and (3) "back-to-back arrangement" where the human-objects face in the opposite direction(Figure 1).

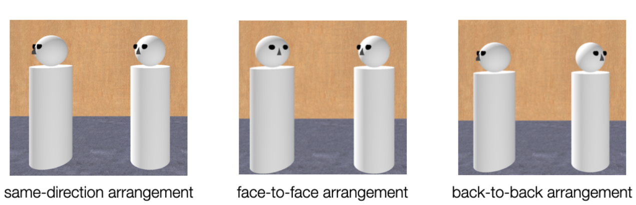

Figure 1: Three types of arrangements.

For each of the eight conditions, two of the three arrangements were combined. Furthermore, the two experiments were conducted to determine whether the left or right aperture should be selected. First, to confirm that there was no size illusion caused by the direction of the human-like objects when selecting apertures, the participants in Experiment 1 were asked, "Which aperture is wider?" The participants in Experiment 2 were asked which of the apertures they would prefer to pass through. In Experiment 1, we hypothesized that in either conditions, no difference was shown in choice of the apertures, because we assumed that the direction of the object would not cause size illusion. In Experiment 2, we hypothesized that the aperture indicating communication (face-to-face) is not selected and that the aperture that does not exhibit communication (back-to-back) is preferentially selected. Therefore, the main hypothesis stipulates that the facing arrangement is not selected , while the rear arrangement is preferentially selected. Specifically, the experiment was conducted under the assumption that the same-direction arrangement is selected based on a combination of face-to-face and same-direction (C1 and C2 in Figure 2); the back-to-back arrangement is selected by combining back-to-back and same-direction (B1 and B2 in Figure 2); and the back-to-back arrangement is selected by combining back-to-back and face-to-face (D1 and D2 in Figure 2).

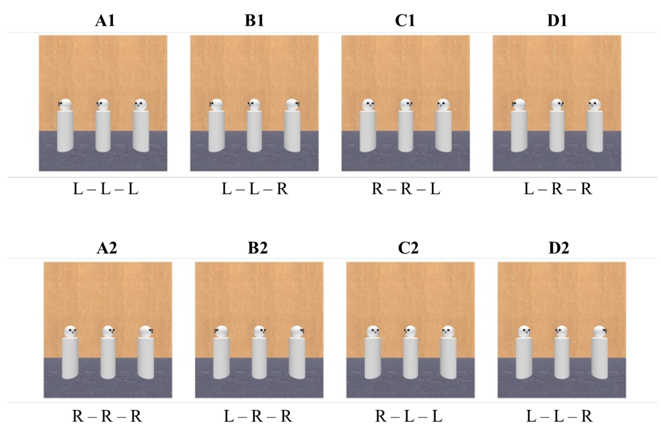

Figure 2: Eight experimental conditions.

Method

Participants

Two experiments (Experiments 1 and 2) were conducted. We recruited 91 and 92 participants for Experiments 1 and 2, respectively, through a crowdsourcing service (Yahoo! Crowdsourcing, Yahoo! JAPAN). This study was conducted in the Japanese language. A reward of 50 PayPay points(an electronic payment system available in Japan) was paid for each participant, which could be used for the service. Participants joined one of the two experiments , not both. This experiment was approved by the Ethics Review Procedures concerning Research with Human Subjects at Waseda University.

Apparatus

This study used an iMac (Retina 5K, 27-inch, 2020) [CPU: 8-Core Intel Core i7, 3.8 GHz, memory: 40 GB, graphics: AMD Radeon Pro 5500 XT], JavaScript [library: p5. js (ver. 0.6.0), Vue.js (ver. 2.6.14), and Vuetify (ver. 2.6.0)] to create the experimental stimuli.

Experimental Design

Both experiments used three human-like objects placed at regular intervals to configure the two apertures with the same width (Figure 2). The human-like objects were oriented in right or left directions. Figure 1 presents the total eight experimental conditions, which are defined as follows: When all three human-like objects are left-oriented (L), they are represented by "L-L-L" (A1 in Figure 2). When all three human-like objects are right-oriented (R), they are represented by "R-R-R" (A2 in Figure 2). Similarly, the directions of human-like objects in all eight conditions are presented in Figure 1. The experimental stimuli of eight conditions were presented randomly.

Procedure

The common procedure between the two experiments is as follows: After checking the consent form items on the computer screen, the participants applied the same size adjustments of the stimuli presented on the screen. Five practice trials were performed before the main trial. In each trial, participants were asked to gaze at a white cross on a black screen presented for 3 s. Subsequently, one of the eight conditions was presented for 5 s, and the screen was switched to a screen where the participants were asked to select either the left or right aperture using a button (Figure 3). The eight conditions were presented randomly, and the experiment was completed in approximately 15 min.

The two experiments varied in task with the following instructions: Experiment 1 asked participants to select the aperture they perceived to be wider. Experiment 2 required participants to select the perceived aperture that they could prefer to pass through.

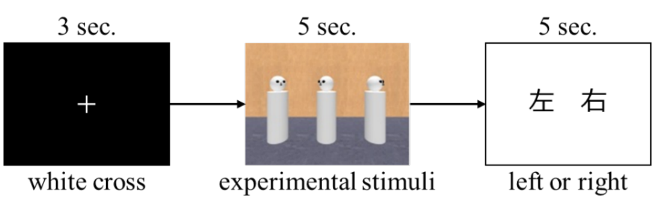

Figure 3: Experimental flow.

Data Analysis

The participants were asked to choose left or right for each stimulus (Figure 2). Particularly, the left and right choices for each condition were aggregated. The results are summarized in Tables 1 and 2. A chi-square test or Fisher's exact test the differences between conditions affected the left-right choices. A residual analysis was also conducted to examine the bias in the choices for each condition. The statistical software js-STAR XR+ version 1.2.0 J (Tanaka & Nakano, 2013) was used in the analysis.

Results

Results of Experiment 1

The results of Experiment 1 are displayed in Table 1. A Fisher's exact test revealed a significant difference ($p<.001$). The effect size calculated from the χ^2 value (w=0.221, 1-β=0.998) was considered small according to the convenience criterion (Cohen, 1992). The power (1-β) was sufficient. In condition D1, a two-tailed test (α=0.05) of the residuals in each cell showed that the right frequency was significantly lower than the expected frequency (z=-4.813, adjusted $p<.001$) while the left frequency was significantly higher than the expected frequency (z=4.813, adjusted $p<.001$). In condition D2, the right frequency was significantly higher than the expected frequency (z=3.209, adjusted $p<.005$), while the left frequency was significantly lower than the expected frequency (z=-3.209, adjusted $p<.005$).

Table 1: Results of Experiment 1.

Condition	Left	Right	Significance
A1	41	50	-
A2	30	61	-
B1	32	59	-
B2	41	50	-
C1	35	56	-
C2	30	61	-
D1	57	34	*
D2	22	69	*

* $p<.05$

Results of Experiment 2

The results of Experiment 2 are shown in Table 2. A χ^2 test demonstrated a significant difference ($\chi^2(7)$ =264.338, $p<.001$, w=0.599, 1-β=1). The effect size was considered large according to the convenience criterion (Cohen, 1992), and the power (1-β) was sufficient. A two-tailed test (α=0.05) of the residuals in each cell revealed that the right frequency was significantly higher in condition A1 than the expected frequency (z=4.672, adjusted $p<.001$), while the left frequency was significantly lower than the expected frequency (z=-4.672, adjusted $p<.001$). In condition A2, the right frequency was significantly lower than the expected frequency (z=-2.938, adjusted p=0.003), while the left frequency was significantly higher than the expected frequency (z=-2.938, adjusted p=0.003).

In condition B1, the right frequency was significantly higher than the expected frequency (z=7.134, adjusted p<.001), while the left frequency was significantly lower than the expected frequency (z=-7.134, adjusted p<.001). In condition B2, the right frequency was significantly lower than the expected frequency (z=-6.295, adjusted p<.001) while the left frequency was significantly higher than the expected frequency (z=6.295, adjusted p<.001). In condition C1, the right frequency was significantly lower than the expected frequency (z=-6.519, adjusted p<.001), while the left frequency was significantly higher than the expected frequency (z=6.519, adjusted p<.001). In condition C2, the right frequency was significantly higher than the expected frequency (z=5.343, adjusted p<.001) while the left frequency was significantly lower than the expected frequency (z=-5.343, adjusted p<.001). In contrast, condition D1 demonstrated that the right frequency was significantly lower than the expected frequency (z=-8.085, adjusted p<.001), while the left frequency was significantly higher than the expected frequency (z=8.085, adjusted p<.001). In condition D2, the right frequency was significantly higher than the expected frequency (z=6.686, adjusted p<.001) while the left frequency was significantly lower than the expected frequency (z=-6.686, adjusted p<.001).

Table 2: Results of Experiment 2.

Condition	Left	Right	Significance
A1	21	71	*
A2	55	37	*
B1	10	82	*
B2	70	22	*
C1	71	21	*
C2	18	74	*
D1	78	14	*
D2	12	80	*

* p<.05

Discussion

Experiment 1

Experiment 1 revealed a significant difference in the combination of the direction of the human-like objects on the perception of aperture width, albeit with a small effect size. Further analysis revealed that significant differences were present only in the D1 and D2 conditions.

This study hypothesized that combining the directions of the human-like objects does not produce the illusion; therefore, it shows no significant difference in all conditions. Although Experiment 1 exhibited a significant difference in the overall effect, a small effect size was produced. The significant difference arose due to the size of the sample size. Thus, the small effect size suggests that this experiment did not have illusory effects on participants' judgment.

Conversely, the residual analysis found that only condition D (D1 and D2) significantly differed from the other conditions. The back-to-back arrangement was preferentially selected, while the face-to-face arrangement was not preferentially selected. Other than condition D, condition B was the only condition that included a back-to-back arrangement. However, no significant difference was found in condition B, which comprises a combination of back-to-back and side-by-side. Moreover, condition C was the only condition other than D that included a face-to-face arrangement. However, no significant difference was found in condition C. The results indicated a preference for back-to-back arrangements and no preference for face-to-face arrangements only when face-to-face and back-to-back arrangements were combined. This indicates that the illusion of perceived width may occur only when these two arrangements are combined. In this study, the two assumed arrangements included an instance where the participants appeared to be communicating (face-to-face arrangement) and not communicating (back-to-back arrangement). Although it is unclear whether the participants regarded communicating as present in these two arrangements, significant insights could be derived if the social factor of communication caused the illusion of width perception. Thus, further study is needed to investigate these issues in more detail.

Experiment 2

Experiment 2 showed that the combination of the direction of the human-like objects influenced the choice decision between the two apertures, showing a sufficient effect size. The residual analysis demonstrated significant differences in all conditions. The experiment was conducted based on the hypothesis that the participants would choose to ignore the face-to-face arrangement and preferentially select the back-to-back arrangement. Significant differences were found in the selection of the aperture in conditions B and C, which included either a face-to-face or back-to-back arrangement. Similarly, this finding was observed in condition D, which included both face-to-face and back-to-back arrangements. The aperture configured in the face-to-face arrangement was avoided, and the aperture configured in the back-to-back arrangement was preferentially selected. Specifically, in conditions B, C, and D, more apertures were selected in a back-to-back facing configuration, same-direction arrangement, and a back-to-back arrangement, respectively. These results were consistent with the hypotheses.

However, significant differences were also observed in condition A, which consisted of only the same-direction arrangement of apertures. In this result, in A1, B1, C2, and D2, participants significantly selected the right aperture more frequently. In these conditions, the human-like object in the center faced left. Conversely, in A2, B2, C1, and D1, participants selected the left aperture significantly more frequently. In these conditions, the human-like object in the center faced right. A consistent and simple interpretation of this result is that participants chose to avoid the gaze of the object in the center when asked to choose a passage through an aperture composed of human-like objects. This interpretation suggests that participants focused merely on the object in the center only. Thus, future studies should examine whether participants only look at the object in the center by using eye trackers and other methods. Two factors can be considered when interpreting this result:

The first factor is the avoidance of interrupting interactions among the objects. Under the condition when two objects are arranged face-to-face, participants could perceive them interacting. In this case, participants might avoid interrupting their interactions and select the other aperture (e.g., the right aperture in condition D2). From the transactional segment perspective (Kendon, 1990), the segment between two face-to-face objects can be defined as the space where they conduct communication activity. Because passing through the aperture could interrupt their communication, participants might select the other aperture.

We consider that these interpretations are based on perception of *social affordance*. Social affordance can be defined as behavioral opportunities for interaction (Eiler, 2015). According to Eiler (2015), participants might perceive human-like objects as *others* and perceive their "interact-ability" (possibilities for interaction provided by others). Further investigation should be conducted to reveal whether participants can perceive human-like objects as others who can interact with them. Furthermore, it is important to investigate what affects the perception and actions of human beings in social environments consisting of virtual human-like objects (e.g., avatars).

The second factor is the avoidance of interrupting objects' transfer or passage. Human-like objects with faces have anisotropic structure. Anisotropy means that the property of an object can vary depending on its direction. For example, an automobile can move forward or backward but cannot move leftward or rightward. In the case of humans, they tend to move to the direction where their face is oriented (Gibson & Crooks, 1938; Tomono et al., 2019). According to such properties, participants could perceive a possibility or tendency of human-like objects' transfer to face direction of the objects. Thus, participants can perceive the possibility or tendency of the transfer direction based on the anisotropic property of the object. As a result, participants avoided selecting the aperture between two objects arranged face-to-face.

General Discussion

In Experiment 1, we asked participants which apertures they thought were wider. In Experiment 2, we asked participants to determine which of the two apertures they preferred to pass through. In conditions A, B, and C, no significant difference was found in the choice in Experiment 1, whereas a significant difference was noted in Experiment 2. The two apertures presented in the experiments were same width. If the direction of the human-like objects had not influenced the participants' choice, the two apertures would have been selected in equal proportions. However, the results of the two experiments showed a difference when people chose to pass through the aperture, although no difference was found in perceived width in the A, B, and C conditions. Therefore, participants preferentially select a particular aperture based on factors other than the width of apertures when attempting to pass between human-like objects.

The first factor assumed in this study was based on whether the human-like objects appeared to be communicating with each other. However, significant differences were also observed in condition A in the passage selection. Therefore, these findings cannot determine whether the presence or absence of communication is necessarily the only factor.

Another factor was based on the anisotropy. The direction in which a human-like object is facing is thought to show a possibility or tendency of transfer or move to that direction (Gibson & Crooks, 1938; Tomono et al., 2019). Based on the anisotropic property mentioned above, participants can perceive the potential direction where the object might move ; thus, they avoid passing through the aperture that can cause interruption of the object's transfer or collision with them.

The result of Experiment 2 showed that participants selected the opposite side of the face direction of the object in the center. This result was interpreted that participants would avoid the potential direction of transfer of the object in the center with an anisotropic structure. However, it is unclear whether collision avoidance, in this case, refers to the object in the center or considers the travel direction of the left and right human-like objects. For example, selecting the left side would impede the progress of the human-like object on the left in the condition A1. In addition to examining whether the participants only underscored the object in the center as described above, conducting an experiment where the object in the center does not exist is necessary. This can be achieved by setting up an even number of objects and thoroughly examining whether this is based on the travel direction or consideration of communication.

In this study, we asked the participants to choose one of two apertures under the various conditions, based on the framework of the aperture crossing experiment (Higuchi et al., 2004; Higuchi et al., 2011; Wagman & Taylor, 2005; Warren & Whang, 1987). Most aperture crossing experiments have focused on one single aperture. In daily life, however, people choose one or some apertures. Further experiments with the framework of this study will contribute to deeper understanding of obstacle avoidance behaviors including aperture passing in every day life.

The type of human-like objects used in this study are an important factor of virtual environments such as VR space or metaverse. For experiments using virtual environments in a field of cognitive science, it is important to investigate how property of virtual objects affect human perception and action. Clarifying the effect of the property of these virtual objects on human perception and action will indicate points to note when conducting experiments using virtual environments and analyzing its results. The results of this study will also provide keys where to place objects to create a better environment when virtual environments are integrated in society.

Acknowledgments

This work was supported by Waseda Research Institute for Science and Engineering, Grant for Scientists. We would like to thank H.Aoe for assistance in revising the English sentences.

References

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159.
Eiler, B. A. (2015). *What it means to be interact-able: A social affordance perspective* Doctoral dissertation, University of Cincinnati .
Gibson, J. J., and Crooks, L. E. (1938). A theoretical field-analysis of automobile-driving. *The American Journal of Psychology, 51,* 453-471. doi: 10.2307/1416145
Hackney, A. L., Cinelli, M. E., & Frank, J. S. (2018). Action strategies for walking through multiple, misaligned apertures. *Acta Psychologica, 182*, 100-106.
Higuchi, T., Murai, G., Kijima, A., Seya, Y., Wagman, J. B., Imanaka, K. (2011). Athletic experience influences shoulder rotations when running through apertures. *Human Movement Science, 30*, 534-549.
Higuchi, T., Takada, H., & Matsuura, Y. (2004). Visual e stimation of s patial r equirements for l ocomotion in n ovice w heelchair u sers. *Journal of Experimental Psychology, 10*, 55-66.
Shaw, E. R., Flascher, M. O., Kadar, E. E. （1995 ）. Dimensions i nvariants for i ntentional s ystems: Measuring the f it of v ehicular a ctivities to e nvironmental l ayout. In J. Flach, P. Hancock, J. Caird & V. Kim (Eds.), *Global p erspectives on the e cology of h uman-m achine s ystems* (Vol 1., pp. 293-357). Hillsdale, New Jersey: Lawrence Erlbaum Associates Press.
Tanaka, S., and Nakano, H. (2013). *R&STAR d ata a nalysis for b eginners*. Shinyo-sha (In Japanese).
Tomono, T., Makino, R., Furuyama, N., & Mishima, H. (2019). How does a walker pass between two people standing in different configurations? Influence of personal space on aperture passing methods. *Frontiers in Psychology, 10,* 2651.
Wagman, J. B., & Taylor, K. R. (2005). Perceiving affordances for aperture crossing for the person-plus-object system. *Ecological Psychology, 17,* 105-130.
Warren, W. H., & Whang, S. (1987). Visual guidance of walking through apertures: Body-scaled information for affordances. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 371-383.