Abstract

Presenting a suggestion of heaviness to a person in a hypnotic trance (e.g., “your arm is getting heavier and heavier”) tends to result in a corresponding change in the person’s body position (e.g., the arm lowers). This phenomenon may be a result of activation of the mirror neuron system, which leads the subject to anticipate actual weight on the arm. The mirror system underlies people’s ability to sense, in the absence of actual sensory input, experiences of other people. Perhaps this system allows the same anticipatory experience regarding non-human objects. In this study, we showed participants a picture of a rubber hand holding what appeared to be a lightweight rubber ball. In reality, the ball was weighted with sand. We instructed participants to move their arms to a horizontal position and hold them immobile. Those participants who knew the actual weight of the ball tended to raise their arms above the horizontal, perhaps in response to their expectation of the need to resist the weight of the ball. This illusional phenomenon might be similar to that induced by the hypnotic suggestion of heaviness. That is, the body’s response may reflect activity in the mirror system, which anticipates greater weight.

Keywords; hypnosis, heaviness suggestion, mirror system, rubber hand, illusion

A Secret of Hypnosis: A Dynamic Rubber Hand Illusion

Hypnosis seems to be a topic of interest to the general public, as evidenced by the numerous television shows that feature hypnotists. However, although a few previous studies in the fields of general psychology or brain research have dealt with hypnosis 1,2, researchers have tended to avoid the topic. Yet scientists study a variety of phenomena that seem as improbable as hypnosis. For instance, there is a large volume of literature exploring visual illusions, a phenomenon that demonstrates that we can see something that does not actually exist 3.

This raises the question of why scientists shy away from studying hypnosis. We suggest that it might be helpful to compare the phenomenon of hypnosis to illusions. This framing calls attention to a feature of hypnosis that differentiates it from illusions, namely the presence of the hypnotist and hypnotic suggestions. This personal element with its potential for bias and influence represents a key reason for skepticism about the possibility of the scientific study of hypnosis. If we are to investigate hypnosis in a scientific way, we must consider the roles of the hypnotist and hypnotic suggestions.

In recent years, Rizolatti and others have explored the mirror neuron system, or mirror system (for a review of this work, see 4). This system allows us to imitate others' behaviors and sympathize with others' mental states, apparently by activation in the observer of neurons that approximate the neurological activity of the person observed. In part, this work has proven valuable in understanding the construct dubbed the theory of mind, namely our ability to recognize and empathize with other's psychological states (for a review of this work, see 5).

For example, it was reported that administering painful stimuli to subjects activated the same brain areas as those activated by a signal indicating that a loved one experienced pain 6. Botvinick and Cohen reported similar results with non-human objects. When subjects observed an object (a rubber hand) being touched, their responses indicated activation of their own sensation of touch, suggesting that subjects "sympathized" even with a non-human object 7. In other words, we understand the outer world through our body, in this case, specifically through the mirror system 8. Insofar as the mirror system is involved, observing another object may arouse anticipation of the same experience in oneself.

Auditory as well as visual stimuli may activate this predictive simulation system. For instance, hearing verbs activates those parts of the motor cortex corresponding to the action named (for a review of this research, see 9). This suggests that hearing a verb may cause people to simulate in themselves actions corresponding to the meaning of the verb. It was demonstrated that expectations for taste operate in a similar manner. When they told subjects that a (cheap) wine was expensive, they observed brain responses similar to those found in response to genuinely expensive wine 10. It appears that subjects tasted the anticipated flavor rather than the actual one. The placebo effect is another, more familiar version of this phenomenon: a substance that has no actual pharmacological effect is often effective in reducing symptoms if the patient expects it to be effective (for a review of this research, see 11, 12).

The mirror system might be helpful in understanding hypnosis. Santarcangelo et al. described a typical case of hypnotic suggestion 2. Hypnotized subjects sat comfortably in an armchair, in a semi-darkened and sound-attenuated room, with their heads fixed and their eyes closed. A hypnotic suggestion of heaviness was administered as follows: "You feel your hand becoming heavier and heavier [pause]. It is falling [pause]. Your arms are also heavy [pause].You can feel them becoming heavier and heavier [pause] and you cannot prevent them from lowering." Following this suggestion, subjects' arms drop lower and lower, as if the prediction of their arms sinking caused them to do just that.

This phenomenon of hypnotic involuntariness has been widely discussed in light of current theories of hypnosis 13. The "role-playing" approach 14 considers the experienced sense of involuntariness, like all hypnotic phenomenology, to be a result of the subject's compliance with the experimenter's request. Socio-cognitive theories 15 interpret the hypnotic behavior as a product of the imagery experienced during hypnosis. Finally, neo-dissociative theories 16 describe a dissociated control of behavior 17.

Our hypothesis combines these theories. The instruction of heaviness, for example, might cause subjects to predict the hand's lowering because the mirror system works to interpret the auditory message through a bodily response. That is, the mirror system directs automatic role playing as subjects unconsciously enact the predicted role. Imagery has an influence in that auditory images predict and thereby activate bodily movement. Finally, behavior is under dissociated control because it is the anticipation of sensations rather than subjects' conscious intention that controls their behavior.

From another viewpoint, there are at least two key elements to hypnotic suggestion 13,18. First, subjects must know in advance what they will experience and what will occur if the hypnotic suggestion succeeds. Second, a good relationship between the hypnotist and the subject is crucial to successful hypnosis. We suggest that the former is essential because subjects can only predict the behavior, and subsequently perform it, if they know in advance what is expected. The latter is important as a basis for the subject's willingness to abide by the hypnotist's suggestion.

If our hypothesis is true, hypnotic suggestion involves predictions, and hypnosis can be understood in the same frame as illusions. If that is the case, hypnosis does not require verbal suggestions. It would be possible to cause subjects to move their hands simply by invoking the mirror system to create the expectation of a sensation of heaviness. For instance, if we present a rubber hand holding a heavy weight, subjects' hands will move as if they are holding the weight themselves.

Method

Participants, Apparatus, and Stimuli

Forty-eight university students (32 men and 16 women, mean age = 18.9 years, range = 18–21 years) participated in the current study. These subjects were recruited randomly from an introductory psychology class participant pool. We obtained written informed consent from all participants before conducting the experiment. All participants reported normal or corrected-to-normal vision, hearing, and somatosensation and no neurological abnormalities. The H. N. Handedness scale 19 revealed no difference in handedness among the four groups. The H. N. Handedness inventory is a revised version of the Edinburgh Inventory 20 designed for Japanese subjects. The scale is often used in Japan to measure or control handedness 21. The averaged handedness score was 7.73, which indicates nearly total right handedness.

The experiment took place in a silent, dim room. To display the visual stimuli and conduct the experiment, we used MATLAB (MathWorks, Natick, MA, USA). The display device (GVD-510-3D, Shenzhen Oriscape Electronic Co., Ltd., Shenzhen, Guangdong, China) was attached to a chin rest, and the participant looked through a device that displayed the image of a 28° visual angle virtual screen (Fig. 1). An eye pad prevented subjects from seeing their hands. We measured subjects' hand positions using a wireless mid-space mouse (BOMU-W24A/BL, Buffalo, Inc., Nagoya, Japan). This device weighed 135 g and was equipped with a gyroscopic sensor that allowed it to be used in the air.

The visual stimuli consisted of pictures of a rubber hand holding a ball, as shown in Figure 2. The weighted ball shown in the visual stimuli (Weighted Ball, Regent Far East, Inc., Ashiya, Japan) weighed 1 kg and was 40 cm round. It appeared to be a normal, lightweight rubber ball but was actually filled with sand to add weight.

Participants were randomly divided into four groups (Figure 3). Subjects in the first group saw a rubber hand holding the weighted ball and also held an identical weighted ball in their hands, which were resting on the table. This group was identified as the BB group (Ball seen, Ball held). The second group saw the rubber hand holding the weighted ball, but held no ball themselves. This group was identified as the BN group (Ball seen, No ball held). The third group saw the rubber hand without a ball, but held a weighted ball themselves. This group was identified as the NB group (No ball seen, Ball held). The fourth group saw the rubber hand holding nothing, and they held no ball themselves. This group was identified as the NN group (No ball seen, No ball held). In the BB and NB groups, subjects held the ball and were therefore aware of its weight. However, although they felt the weight of a ball in their hands, they did not actually lift it. In the NN and BN group, subjects had no information about the weight of the ball.

Procedure

Before beginning the experiment, we briefly trained participants to familiarize them with the instruments and experimental requirements. Participants sat in front of the chin rest and placed their chins on it. The apparatus was arranged so that the screen appeared to be located just beyond subjects' reach (about 60 cm). For the actual experiment, we instructed each subject to hold the indicated hand in a horizontal position throughout the trial, which lasted 45 seconds. In each trial, the participant first held the arm out straight using the mouse device to ensure a horizontal position (Figure 3). When the arm was properly positioned, the subject clicked the mouse button once. Following a random interval of 1–2 seconds to allow for micro-motions caused by clicking the mouse, the visual stimulus appeared on the virtual screen. We instructed the subject to remain immobile when the stimulus appeared. We then recorded the height of the mouse device every second throughout the remainder of the trial. After 45 seconds, we instructed the subject to lower the hand and relax. Each subject completed two trials: one with the right hand and one with the left hand. The rubber hand in the visual display matched the participant's hand that was currently in use (see Figure 2). The order of presentation was counterbalanced among the participants.

After the experiment, subjects completed a questionnaire designed to measure the extent to which they felt as if the rubber hand were their own hand and therefore actually felt the weight of the ball presented on the screen. We explained that the purpose of the questionnaire was simply to provide information about participants' impression of the task, and encouraged them to answer freely. We expected that this instruction would avoid the possibility that experimenter effects or demand characteristics might influence the subjects' responses. The questionnaire consisted of five items, each of which asked subjects to rate the accuracy of a particular statement using a five-point scale. The statements, developed by consulting previous research 7, were as follows: 1. Your hand felt the weight of the ball. 2. It felt like your hand was moving lower. 3. It seemed as if the ball was on your own hand. 4. It seemed as if the hand on the screen was your own hand. 5. It felt as though your hand was weary and numb. Because they had neither seen nor held the ball, participants in the NN group answered only three questions: 2, 4, and 5.

Results

We first analyzed the results of the questionnaires (see Figure 4). Results indicated that the BB group scored higher than any other group on all questions. For statistical analysis, we averaged scores over all five scales. Because the NN group did not answer questions 1 and 3, we conducted separate analysis of variance (ANOVA) calculations examining all five questions for just three groups (5 x 3, questions x groups) and then three questions for all four groups (3 x 4, questions x groups). The results of these analyses were analyzed further with Ryan's method. In both cases, these calculations revealed significant main effects for groups: $F(2.33) = 8.23$, $p < .01$; and $F(3.44) = 2.99$, $p < .05$, respectively. Main effects for the questions were also significant in both cases: $F(4.132) = 39.74$, $p < .01$; $F(2.88) = 89.51$, $p < .01$, respectively. Comparisons among the three groups who answered all five questions revealed significant differences between the BB and BN groups ($p < .01$), and between the BB and NB groups ($p < .01$). Comparisons among the four groups on the three questions answered by them all revealed significant differences between the BB and BN groups ($p < .01$), and between the BB and NB groups ($p < .05$). These findings suggest that the BB group experienced most strongly the subjective sense that the rubber hand was their own hand and thus felt the weight of the ball displayed on the virtual screen.

We next examined hand position during the experiments to determine whether these subjective responses were reflected in the objective measurements. Figure 5 shows the time course of participants' average hand positions for each condition over the 45-second trial period. Results for the left hand condition show no clear relationship to group membership. However, under the right hand condition, the hand positions of those in the BB group moved progressively higher while the positions of those in the BN group moved progressively lower. We conducted a one-way ANOVA followed by multiple comparisons using Ryan's method to examine the final hand positions of the four groups. These analyses demonstrated a significant main effect for groups under the right hand condition: $F(3.34) = 3.67$, $p < .05$. The left hand condition showed no significant effect. Calculations of group differences for the right hand condition alone revealed a significant difference between the BN group and the BB group ($p < .01$).

To examine whether each value differed from zero, we conducted *t*-tests. These analyses revealed that only the BB group under the right hand condition was significantly different from zero ($t = 5.71$, $p < .05$). The difference in the BN group was not significant (t(22)=2.64, P=.06). Finally, we used a χ^2 test to compare differences in the number of participants in each group whose hands moved higher or lower by the end of the trial. Under the left hand condition, no group differences were found in this measure (the numbers of participants in the BB, BN, NB, and NN groups whose hands moved higher were six, six, seven, and six, respectively). However, under the right hand condition, the number of participants in the BB group whose hands moved higher was significantly greater, and values in the BN group were significantly smaller than expected (ten and three participants, respectively; $\chi^2 = 8.93$, $p < .05$). In the NB and NN groups, these numbers were seven and five, respectively.

According to the questionnaire results, participants in the BB group subjectively felt the weight of the ball most strongly. Given instructions to keep their hand horizontal throughout the trial, subjects may have felt a need to adjust to the perceived weight. In the absence of actual weight, we might expect their hands to move higher as they tried to compensate for the (perceived) added weight. Although it is unclear why this process would affect only the right hand, the finding that participants in the BB group raised their hands over the course of the trial is compatible with the hypothesis that they were compensating for the subjective sense that they were holding a weighted ball.

Alternatively, the difference between the BB and BN groups might be a result of the tendency for participants in the BN group to lower their hands. It is possible that members of the BN group were more susceptible to experimenter effects or demand characteristics. Since they saw the ball on the rubber hand and were explicitly instructed to keep their hands immobile (that is, not to be affected by the visual stimuli), they may have concluded that the experimenter expected them to lower their hands in response to the visual stimuli. In that sense, the BN condition might represent an unconscious role-play condition, even if the participants were consciously attempting to keep their hands immobile.

Discussion

Results of the present study suggest that seeing the rubber hand with a ball might have activated the mirror system, leading participants to feel the weight they assumed the ball carried. Those who held a ball themselves and thereby knew its actual weight were susceptible to this effect and responded by raising their hands. In contrast, participants were able to keep their hands immobile if they did not see the ball in the rubber hand (as in the NN group). Further, holding a ball in the other hand did not affect the target hand (as reflected in data for the NB group). Participants who saw the ball on the rubber hand (BB and BN groups) tended to respond by moving their hands. Participants who knew the ball's actual weight (the BB group) raised their hands, while those who did not know its weight (the BN group) lowered their hands, perhaps because of unconscious role playing. The key factor appears to be whether participants knew the weight of the ball in the picture. That is, knowing the weight of the ball and experiencing the ball as if it were actually in their hand resulted in participants raising their arms over the course of the trial to compensate for or resist the (perceived) sensation of weight.

This illusional phenomenon, which we call the dynamic rubber hand illusion, may reflect a two-step process. First, participants may sympathize with the rubber hand, simply by seeing it, as occurred in the rubber hand illusion described by Botvinick and Cohen 7. This may occur through the activation of the mirror system. This step was reflected in the finding that some participants felt as if the rubber hand were their own hand and subjectively experienced the weight of the ball; this was most prominent among participants in the BB group. Second, this sympathetic response may affect our bodies as if we were actually experiencing the stimulation (in this case, the weight).

These results may make it possible to discriminate between conflicting explanations for this phenomenon. An explanation involving socio-cognitive role playing stresses social factors such as experimenter effects or demand characteristics and would focus on what the participants assume the experimenter wants (e.g., the participants believe that the experimenter expects them to move their hands lower). This explanation would predict different findings than one involving automatic mirror systems, which would predict that participants would raise their arms in response to mirror system-mediated anticipation of added weight. In this vein, it was showed that the motion trajectories in a role-playing condition might differ from those in a hypnotic suggestion condition 2. Thus it appears that the results of the present study cannot be fully explained by experimenter effects or role-playing, nor are the results of hypnotic suggestion easily explained using these models.

The present study demonstrated that seeing the rubber hand with a weighted ball could cause participants to move their hands higher. Although this was simply one of the illusions, it may suggest scientific hypotheses about how hypnosis works. Specifically, the behavior may reflect the operation of the mirror system, which translates information from the outer world into motor responses based on empathic understanding of that world. In short, participants' hands moved higher because they (subjectively and empathically) felt that the weight in their hands demanded muscular accommodation, which in turn resulted in their raising their arms.

Second, what has been called hypnotic suggestion might simply mean anticipating what will occur in the future. That anticipation is sufficient to cause bodily responses—sensations of touch, taste, or pain, and even improvement in medical conditions 6,7,9,10,11. Indeed, hypnosis itself might be irrelevant to a hypnotic subject's lowering of her or his arm. Santarcangelo et al. demonstrated that the motor strategy of non-hypnotized subjects who listened to suggestions of heaviness was similar to that of hypnotized participants 2, a finding that suggests that the power of hypnotic suggestion lies in the words rather than in the process.

Third, the research on heaviness suggestions yielded results that appear to be the opposite of those found in the present study (i.e., subjects' hands moved lower in the former but higher in the latter). However, the present study raises an important question: what would happen if a hypnotist were to suggest that the participants' hands are heavy but then instruct subjects not to lower their hands? Such a situation would more nearly match the arrangement of the present study, and the question allows us to see more clearly the connection between the scientific illusional phenomena and hypnosis.

It remains unclear why only the right hand was affected in this study. Indeed, a previous study reported similar but opposite right-left asymmetry in response to suggestions of heaviness 2. In that case, the left arm was lowered earlier and to a greater degree than the right arm. The researchers in that study interpreted their findings in terms of hand/brain asymmetry in automatic or executive movements. This is also related to an attentional bias toward the right hand 22. That is, the left hand might be under greater automatic control than the right and therefore be more affected by hypnotic suggestion. The right hand, in contrast, may be under greater executive control and therefore be less affected by the hypnotic suggestion of heaviness. In the case of the present study, participants would have called upon executive control to keep their hands immobile, contrary to the heaviness suggestion. This might have resulted in the right hand being more sensitive to the anticipated (illusory) weight. At the same time, under executive motor control, the non-preferred arm and hemisphere might be more adept than the preferred side at utilizing position-related proprioceptive information 23. Thus, it might be easier for participants to hold their left hands immobile when instructed to do so. Further research about potential laterality is needed to clarify this possibility.

Although the present research yielded some interesting findings, it had several limitations. In this study, each participant completed only two trials, one using the left hand and one using the right hand. This format was based on previous research that included three repeated trials and showed no change in the effect of hypnotic suggestion from the first trial to the third 2. However, the absence of repeated trials in the present study resulted in statistical weakness in our analyses. Future research should examine whether these hypnotic suggestions would be effective across many trials. Considerable individual differences also contributed to the weak statistical results reported here. It is well known that some people are easily affected by hypnotic suggestions (e.g., hypnotizability, suggestibility, or sensitivity; 13). Because the variables entailed in this individual variation remain unclear, the present study did not control for individual differences despite the literature suggesting their importance1,2. Among the factors involved may be variations in the sensitivity of the mirror system, which could be significant in examining the relationship between hypnosis and the automatic mirror prediction system. Indeed, such individual factors seem to be related to the vividness of imagery in vision or action 2. Further research is needed to explore these issues.

References

1 Blakemore, S. J., Oakley, D. A., & Frith, C. D. (2003). Delusions of alien control in the normal brain. *Neuropsychologia, 41*, 1058-1067.

2 Santarcangelo, E. L., Cavallaro, E., Mazzoleni, S., Marano, E., Ghelarducci, B., Dario, P., Micera, S., & Sebastiani, L. (2005). Kinematic strategies for lowering of upper limbs during suggestions of heaviness: a real-simulator design. *Experimental Brain Research, 162*, 35-45.

3 Kanizsa, G. (1979). *Organization in Vision: Essays on Gestalt Perception*. Praeger, New York.

4 Fabbri-Destro, M., & Rizzolatti, G. (2008). Mirror neurons and mirror systems in monkeys and humans. *Physiology* (Bethesda), *23*, 171-179.

5 Premack, D. (2007). Human and animal cognition: continuity and discontinuity. *Proc Natl Acad Sci USA, 104*, 13861-13867.

6 Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*, 1157-1162.

7 Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391*, 756.

8 Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience*.

9 Pulvermüller, F. (2005). Brain mechanisms linking language and action. Nature Review *Neuroscience, 6*, 576-582.

10 Lassmann, H., O'Doherty, J., Shiv, B., & Rangel, A. (2008). Marketing actions can modulate neural representations of experienced pleasantness. *Proc Natl Acad Sci USA, 105*, 1050-1054.

11 Howland, R. H. (2008a). Understanding the placebo effect. Part 1: placebo use in clinical trials. *Journal of Psychosocial Nursing and Mental Health Services*, *46*, 17-20.

12 Howland, R. H. (2008b). Understanding the placebo effect. Part 2: underlying psychological & neurobiological processes. *Journal of Psychosocial Nursing and Mental Health Services, 46*, 15-18.

13 Nash, M. R., & Barnier, A. J. (2008). *The Oxford Handbook of Hypnosis: Theory, Research and Practice*. Oxford University Press, Oxford.

14 Wagstaff, G. F. (1999). The semantics and physiology of hypnosis as an altered state: toward a definition of hypnosis. *Contemporary Hypnosis, 15*, 149-165.

15 Lynn, S. J., Rhue, J. W., & Weeks, J. R. (1990). Hypnotic involuntariness: a

social-cognitive analysis. *Psychological Review*, 97, 169-184.

16 Kirsch, I., & Lynn, S. J. (1998). Dissociation theories of hypnosis. *Psychological Bulletin, 123*, 100-115.

17 Bowers, K. S. (1992). Imagination and dissociation in hypnotic responding. *International Journal of Clinical and Experimental Hypnosis, 40*, 253-275.

18 Streeter, M. (2004). *Hypnosis: Harnessing the Power of the Subconscious Mind*. New Burlington Books, London.

19 Hatta, T., & Kawakami, A. (1995). Patterns of handedness in modern Japanese: a cohort effect shown by re-administration of the H.N. Handedness Inventory after 20 years. *Canadian Journal of Experimental Psychology, 49*, 505–512.

20 Oldfield, R.C. (1971). The assessment and analysis of handedness: the Edinburgh Inventory. *Neuropsychologia, 9*, 97-113.

21 Ogawa, K., Inui, T., & Sugio, T. (2006). Separating brain regions involved in internally guided and visual feedback control of moving effectors: an event-related fMRI study. *Neuroimage, 32*, 1760-1770.

22 Peters, M. (1981). Attentional asymmetries during concurrent bimanual performance. *Quarterly Journal of Experimental Psychology, 33*, 95-103.

23 Goble, D. J., Lewis, C. A., & Brown, S. H. (2006). Upper limb asymmetries in the

utilization of proprioceptive feedback. *Experimental Brain Research, 168*, 307-311.

The English in this document has been checked by at least two professional editors, both native speakers of English. For a certificate, see:

http://www.textcheck.com/cgi-bin/certificate.cgi?id=JMMujy

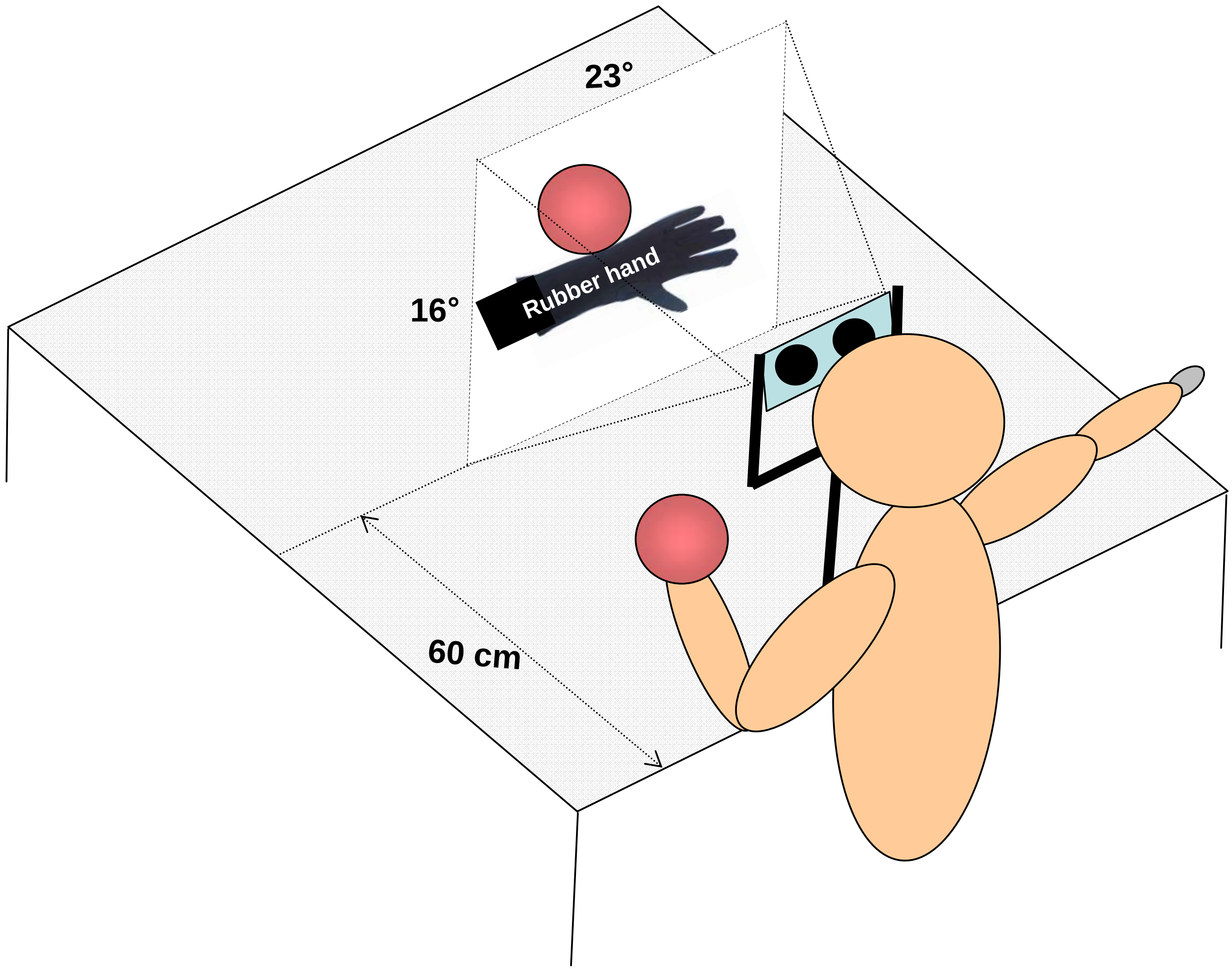

Fig. 1. Illustration of the experimental apparatus.

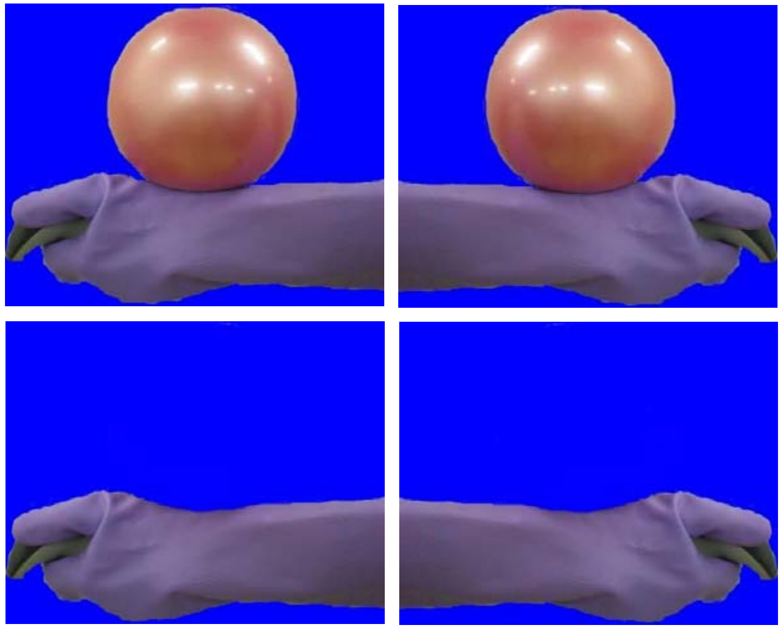

Fig. 2. The actual visual stimuli in the experiments.

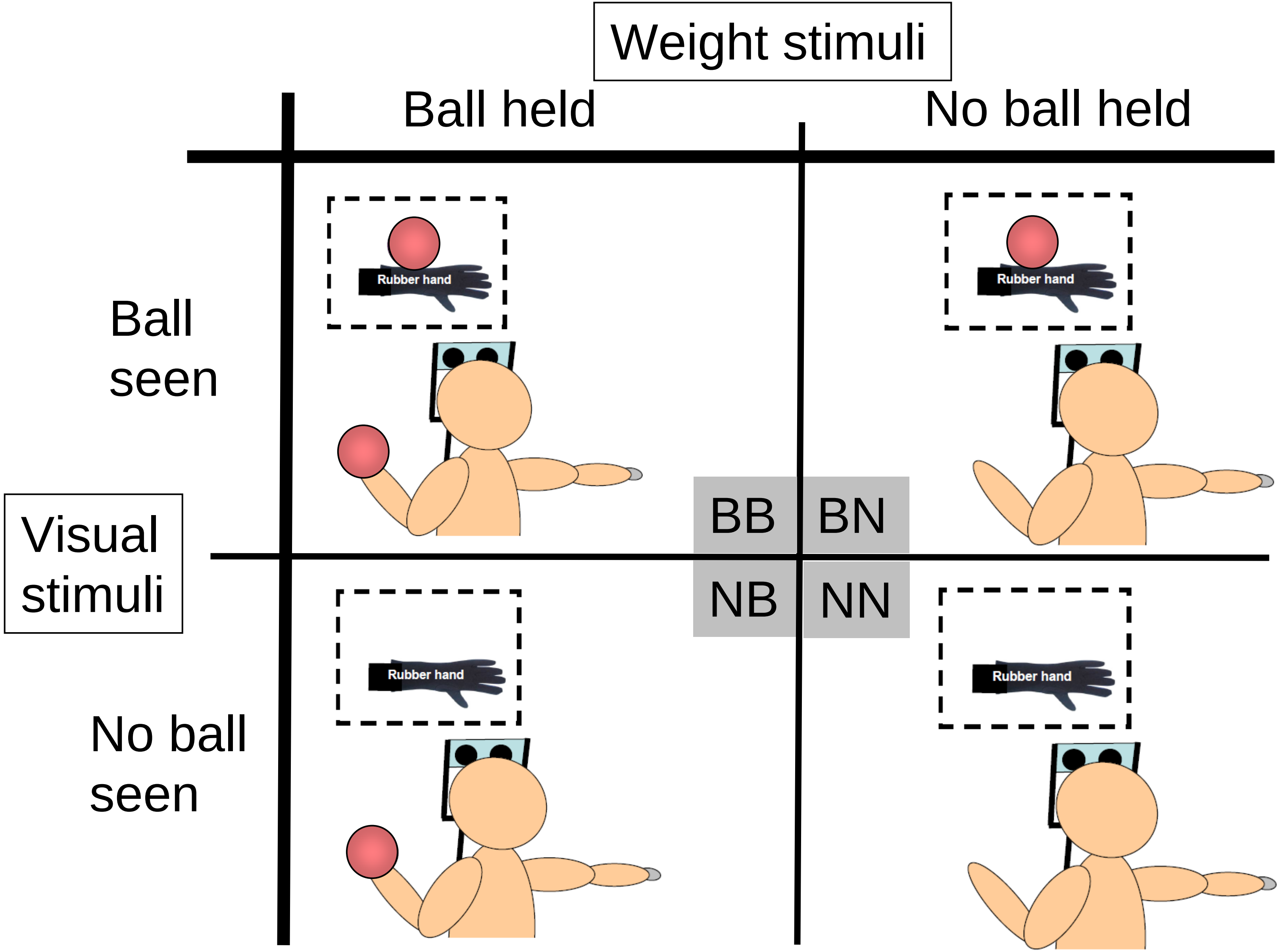

Fig. 3. Illustration of the experimental design (2 ×2).

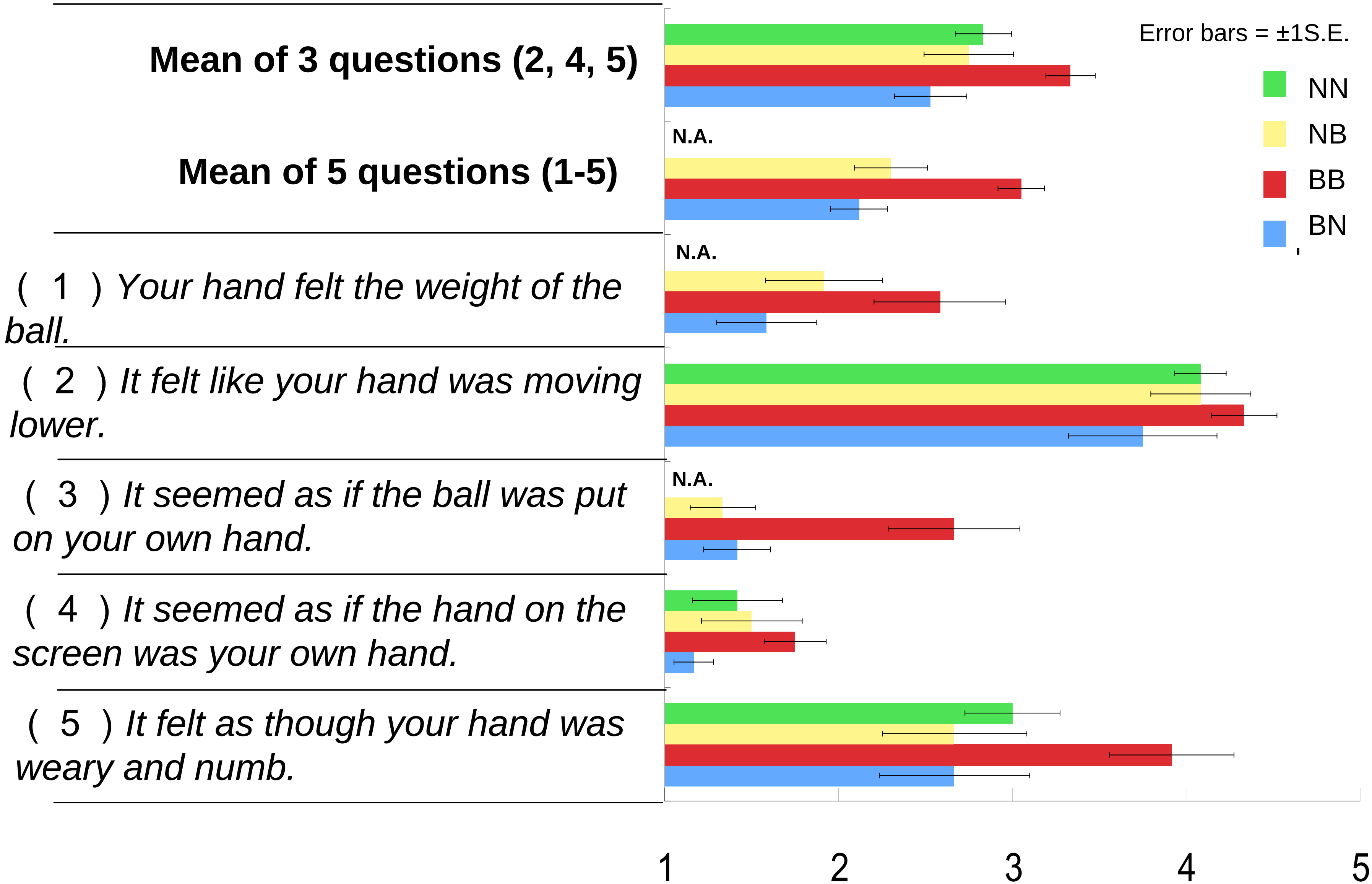

Fig. 4. The relationships between the 4 groups and the questionnaire scores.

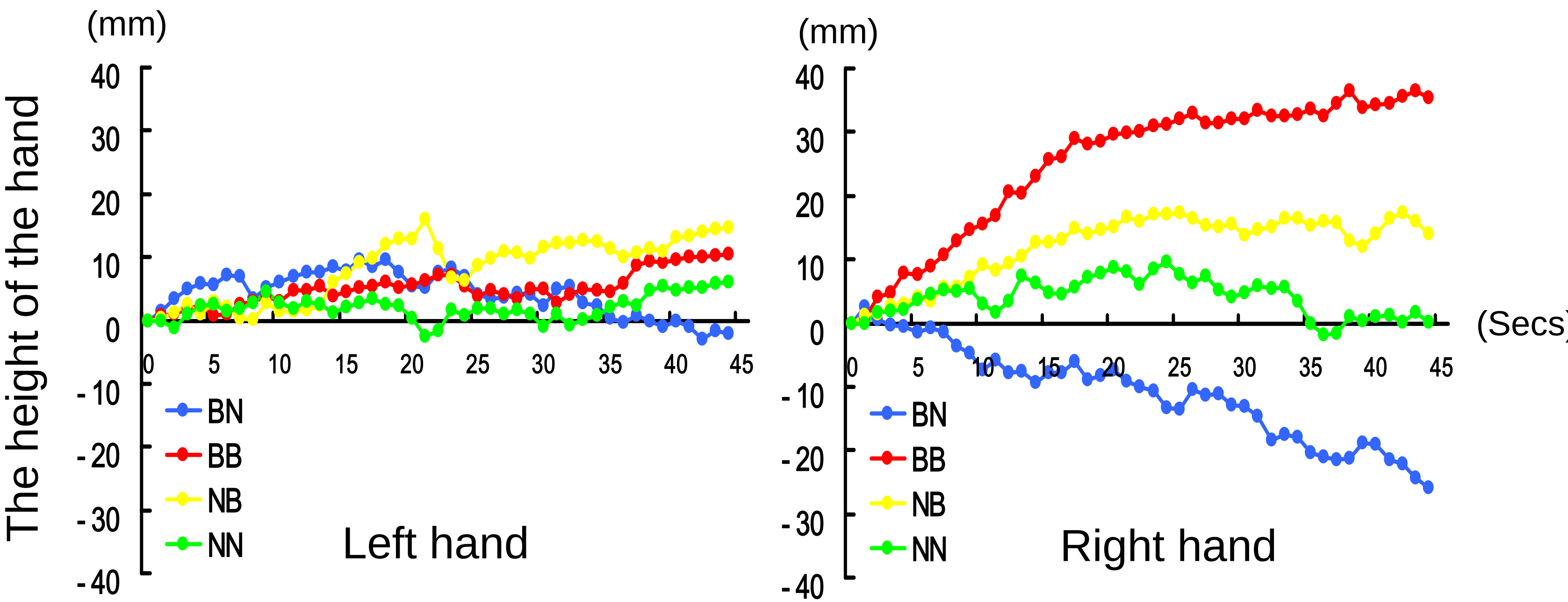

Fig. 5. The relationships between the 4 groups and the experimental results.