# The transfer of motion direction learning to an opposite direction enabled by double training: A reply to Liang et al. (2015)

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A recent paper from our lab (Zhang & Yang, 2014) reports that perceptual learning of motion-direction discrimination, which is known to be specific to the trained direction, can transfer significantly, and sometimes completely, to an opposite direction, provided that the observers receive additional exposure of the opposite direction via an irrelevant task. However, in a newly published study, Zili Liu and collaborators claim that they cannot replicate our original double training results using identical procedures (Liang, Fahle, & Liu, 2015). Here we point out that the relevant data in Liang et al. (2015) are actually not very different from those in Zhang and Yang (2014). We thus pool data from both studies to obtain a more precise estimate of the transfer rate, which is over 75% of the learning effect.

Visual perceptual learning (VPL) is known to be location and feature specific, which is often taken as evidence for training-induced neural plasticity in early visual areas (e.g., Ball & Sekuler, 1982; Karni & Sagi, 1991; Schoups, Vogels, & Orban, 1995). However, in collaboration with Dennis Levi and Stanley Klein, we have developed new ''double-training'' techniques to enable VPL of various tasks to transfer to untrained locations and orientations/directions (Wang, Cong, & Yu, 2013; Wang, Zhang, Klein, Levi, & Yu, 2012, 2014; Xiao et al., 2008; Zhang & Yang, 2014; Zhang et al., 2010). For example, Vernier learning can often transfer to a new location or orientation completely if the observers receive additional exposure to the transfer location or orientation via performing an irrelevant task (Wang et al., 2012, 2014; Zhang, Cong, Klein, Levi, & Yu, 2014). Other labs replicated these transfer effects in orientation and Vernier learning tasks using similar double-training procedures (Hung & Seitz, 2014; Mastropasqua, Galliussi, Pascucci, & Turatto, 2015). These transfer results argue against a low-level explanation of VPL by suggesting that VPL may mostly occur in high-level brain areas. They also advance the reweighting theories of VPL (e.g., Dosher & Lu, 1998; Mollon & Danilova, 1996) by suggesting that VPL involves learning of generalizable rules of reweighting the visual inputs (Zhang et al., 2010). Our recent evidence suggests that these rules are conceptual, in a sense that learning can transfer between physically distinct stimuli that are initially decoded by different neural mechanisms (e.g., between local and global orientations defined by gratings and symmetric dot patterns, or between first- and second-order motion directions; Wang et al., in press).

Recently one study from our lab on the transfer of motion direction learning (Zhang & Yang, 2014) is challenged by Zili Liu and collaborators (Liang et al., 2015). Liang et al. (2015) used identical procedures obtained from us. In Zhang and Yang (2014), in experiment 1 the observers ( = 6) practiced a motion-direction discrimination task by judging which of the two consecutively presented motion stimuli moved in a more clockwise direction (each motion stimulus pattern consisted of a group of coherently moving random dots). The learning effects first transferred very little to an opposite direction, replicating direction specificity with a transfer index (TI) of 0.17

transfer, TI $\geq 1$ would indicate complete learning transfer, and $0 < \text{TI} < 1$ would indicate various degrees of partial transfer. However, after the observers continued to practice a dot-number discrimination task (which dot pattern contained more dots?) while the dot pattern was moving at the opposite transfer direction (hence the exposure of the transfer direction), learning transferred significantly to the opposite direction, with the TI increased to $0.62 \pm 0.21$ (replotted here in Figure 1; $= 4.13$, $= 5$, $= 0.009$, paired two-tailed test because of the within-subjects comparison). In experiment 2 the motion-direction training and the dot-number discrimination training were performed in alternating blocks of trials in the same sessions. This time we found more transfer with $\text{TI} = 1.20 \pm 0.36$ (replotted in Figure 1; $= 2.63$, $= 10$, $= 0.025$, unpaired two-tailed test when compared to the baseline TI from experiment 1), suggesting complete learning transfer with the participating observers ( $= 6$). However, learning transferred less to other directions without the direction exposure ($\text{TI} = 0.47 \pm 0.20$). We thus concluded that our new training method enabled ‘‘significant and sometimes complete transfer’’ of motion-direction learning (Zhang & Yang, 2014).

Liu and collaborators decided to replicate our study. We did our best to facilitate their efforts including providing the Matlab codes. Recently they published their results in a paper “Specificity of Motion Discrimination Learning Even with Double Training and Staircase” (Liang et al., 2015). They repeated experiment 2 in Zhang and Yang (2014) using procedures identical to ours before they continued the training for extra sessions. On the basis of the results they made the claim that ‘‘To our surprise, we could not even replicate the original result in Zhang and Yang (2014) with the first seven sessions of data, despite our effort to replicate the experiment as faithfully as possible and in two laboratories’’ (the second paragraph of General discussion in Liang et al., 2015, p. 8).

However, regardless of the strong claim Liang et al. (2015) made, the results in Liang et al. (2015) are actually not very different from those in Zhang and Yang (2014). We had three lab members independently estimate the individual threshold values in the first seven sessions in Liang et al. (2015), on the basis of an enlarged version of their figure 2 (their extra sessions were not replications of our experiments). We then averaged the three estimates for each data point for further calculations. The threshold improvements with the trained direction and the exposed transfer experiments 1 and 2 in Zhang and Yang (2014) are also plotted for comparisons. Among the six observers in Liang et al. (2015), two actually showed nearly complete learning transfer (TIs = 1.00 and 0.93, respectively), three showed about half learning transfer (TIs = 0.59, 0.60, and 0.43, respectively), and one showed negative learning transfer (TI = −0.71).

We compared the transfer effects in Liang et al. (2015) and in Zhang and Yang (2014), which overlap greatly as shown in the two plots of Figure 1. There was no significant difference of TI values between Liang et al. (2015) and our experiment 1 ( = 0.42, = 10, = 0.68, unpaired two-tailed test). Neither was the difference between Liang et al. (2015) and our experiment 2 ( = 1.66, = 10, = 0.13, unpaired two-tailed test). Therefore, the null hypothesis that two studies produced the same amount of learning transfer cannot be rejected by the current data.

A more constructive way to look at the data from both studies is to pool them together to increase the power of the statistical analysis and obtain a more precise estimate of the double training effect. The mean TI index from all 18 observers, including those in experiments 1 and 2 of Zhang and Yang (2014) and in figure 2 of Liang et al. (2015) is 0.77 ± 0.17. In addition, we have run additional six observers in a separate experiment with identical procedures except that the transfer direction was orthogonal to the trained direction (Xiong, Xie, & Yu, 2016). When these six observers' data are included to increase the number of observers to 24, the mean TI = 0.78 ± 0.13, similar to the mean from 18 observers but with smaller error bars ( < 0.001 when compared to TI = 0, and = 0.037 when compared to the baseline TI in experiment 1 in Zhang and Yang, 2014). These results demonstrate that double training indeed is able to enable substantial transfer of motion direction learning to untrained directions.

## Acknowledgments

JYZ and CY are supported by Natural Science Foundation of China Grants 31470975 and 31230030. We thank Stan Klein and Dennis Levi for their helpful comments on an earlier version of this letter.

Commercial relationships: none.
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