VISUAL EFFECTS OF THE INTENDED ACTION GOAL INFLUENCE MANUAL CHOICE REACTION TASKS IN VIRTUAL ENVIRONMENTS

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INTRODUCTION

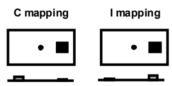
Our actions are performed to attain goals. Representations of intended goals might guide actions by controlling the selection and execution of appropriate motor patterns. Spatial stimulus-response (S-R) correspondence affects human action planning by enhancing performance both when spatial information is task-relevant (Spatial S-R Compatibility effect) and when it is task-irrelevant (Simon effect). Moreover, a spatially incompatible practicing (Proctor and Lu, 1999), inducing a long-lasting modality-aspecific remapping of S-R spatial relations (Tagliabue, Zorzi and Umiltà, 2002), inverts a subsequent Simon effect.
We studied the functional role of action-effect representations in voluntary action planning during manual choice tasks. Our goal was to investigate whether and how spatial relations between *cognitive* (Stimulus), *kinesthetic* (motor Response), and *visual* (Goal) information influence performance. For this reason, we developed 3D experimental conditions simulating ecological (i.e., everyday-life-like) behaviours (car driving tasks) supposed to be affected by intended action goals.

Experiment 1

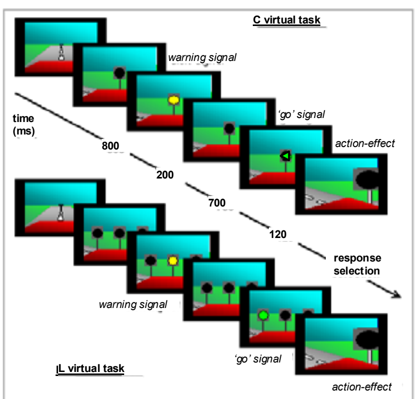
We tested whether non-immersive spatially compatible/incompatible practicing affects a subsequent virtual navigation.

METHODS

Non-immersive Spatial Compatibility Tasks consisted in two conditions: after the onset of a visual stimulus, subjects were required to push either an ipsilateral (*Compatible mapping*) or a contralateral (*Incompatible mapping*) button.



Virtual Navigation Tasks consisted in two virtual car driving conditions. A car autonomously moved along a back straight and stopped at a crossroad: in one condition, a 'go' signal (a left or right oriented arrow) appeared in a central traffic light (***C virtual task***); in the other condition, there were three traffic lights and the 'go' signal (a green light) appeared in one of the laterals (***L virtual task***).
Subjects, using a joystick, were required to drive the car to the indicated direction. After the response, the car turned towards the selected direction and the panorama moved consistently, affording a visual feedback of the action-effect.



Total trials: 72 per task (36 left/36 right)

Subjects. 32 healthy subjects (31 right-handed, 12 males), with normal or corrected-to-normal vision, were randomly and equally distributed within different combinations of *practicing – virtual navigation* tasks.

RESULTS and DISCUSSION

Non-immersive Spatial Compatibility Tasks. The ANOVA on correct RTs, with *Practicing* (*C mapping* vs. *I mapping*) as between subjects factor and *Stimulus Position* (*left* vs. *right*) as within subjects factor, yielded the main effect of *Practicing* (p<0.001), indicating that RTs were faster in *C* than in *I mapping* (286 vs. 382 ms): *Spatial S-R Compatibility effect*.
Virtual Navigation Tasks. The ANOVA on correct RTs, with *Practicing* (*C mapping* vs. *I mapping*) and *Virtual Task* (*C* vs. *L*) as between subjects factors, yielded main effects of both *Practicing* (p<0.05) and *Virtual Task* (p<0.01): performances in virtual navigation tasks were better after a practicing with compatible than with incompatible mapping (454 vs. 485 ms). Moreover, RTs were slower when the stimulus was lateral (*L Virtual Task*, 443 ms) than when it was central (*C Virtual Task*, 495 ms).

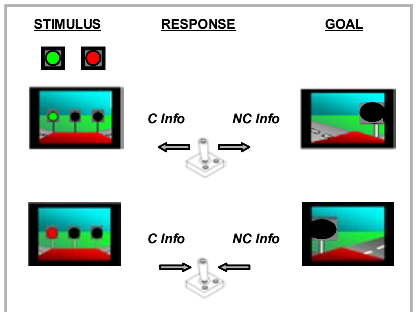
Non-immersive spatially compatible practicing facilitates performance during virtual navigation, instead non-immersive spatially incompatible practicing inhibits it.

Experiment 2

We tested Spatial S-R Compatibility in 3D navigation task, by manipulating spatial relations between *cognitive* (Stimulus), *kinesthetic* (motor Response) and *visual* (Goal) information.

METHODS

Environment and timing of *L Virtual Task* (Experiment 1) were used. The 'go' signal was a green/red light: when a lateral traffic light turned *green*, subjects were required to move car towards its side; when it turned *red*, they were required to move car towards the opposite side.
Experimental conditions were two: to make visual information turn into the proper directions (car and panorama), subjects had to move the joystick either *ipsilaterally* (coordinated information, ***C Info***) or *contralaterally* (non-coordinated information, ***NC Info***) to 'go' signal (see below).



Total trials: 144 per task [76 left (36 green/36 red) and 76 right]

S-R, S-G and G-R spatial relations differed in C Info and NC Info conditions as follows:

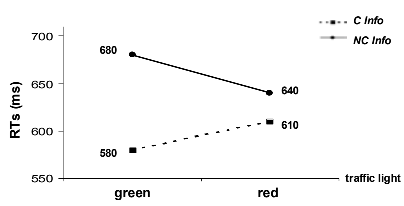
	C Info		*NC Info*	
S-R relation	x	o	o	x
S-G relation	x	o	x	o
G-R relation	x	x	o	o

x = spatial compatibility
o = spatial incompatibility

Subjects. 64 healthy right-handed subjects (all female), with normal or corrected-to-normal vision, were randomly and equally distributed within different combinations of *C* and *NC Info* conditions.

RESULTS and DISCUSSION

The ANOVA on correct RTs, with *Information* (*C Info* vs. *NC Info*) as between subjects factor and *Colour* (*green* vs. *red*) and *Stimulus Position* (*left* vs. *right*) as within subjects factors, yielded the main effect of *Information* (p<0.01): performances were better in *C Info* than in *NC Info* (595 vs. 660 ms), indicating a Spatial G-R Compatibility effect.
One-way ANOVAs on separated colours, with *Information* as between subjects factor, revealed that the found Spatial G-R Compatibility effect occurred only when the traffic light was *green* (p<0.001).
A significant two-way interaction between *Information* and *Colour* (p<0.001) and Post-hoc tests (Newman-Keuls) indicated that RTs were faster both in *C Info* when traffic light was *green* (580 vs. 610 ms, p<0.001), and in *NC Info* when traffic light was *red* (640 vs. 680 ms, p<0.001). It showed a Spatial S-R Compatibility effect and the absence of a S-G Compatibility effect.



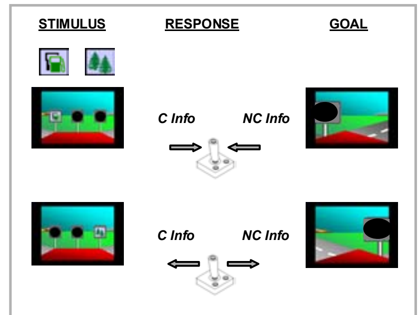
The Spatial G-R Compatibility effect interacts with spatial S-R compatibility. Indeed, when the traffic light was *red*: in *C Info*, G-R compatible trials were slower because they were S-R incompatible, instead, in *NC Info*, G-R incompatible trials were faster because they were S-R compatible.
Therefore, when S-R spatial information is task-relevant, visual feedback (the goal) of an action is not decisive in determining spatial correspondences affecting performance, but response is.

Experiment 3

We tested Simon effect in 3D navigation task, by manipulating spatial relations between *cognitive* (Stimulus), *kinesthetic* (motor Response) and *visual* (Goal) information.

METHODS

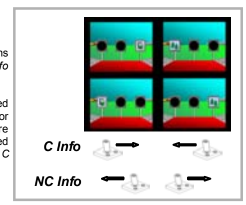
Environment and timing of Experiment 2 were used, but background presented some mountains in one side and a city in the other. The 'go' signal was a traffic sign indicating either a gas station or a forest: when in a lateral traffic light appeared the former, subjects were required to move the car towards the city; when appeared the latter, they were required to move the car towards mountains.
As in Experiment 2, in order to direct properly the car by joystick, subjects received either coordinated (***C Info***) or non-coordinated (***NC Info***) information (see below).



Total trials: 144 per task (36 for each stimulus position)

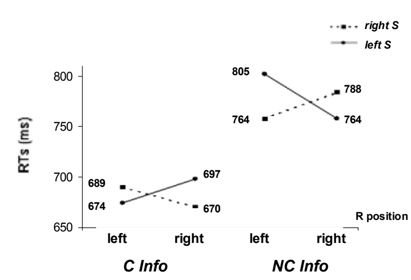
S-R, S-G and G-R spatial relations differed in *C Info* and *NC Info* conditions (as shown in the figure).

Subjects. 96 healthy right-handed subjects (all female), with normal or corrected-to-normal vision, were randomly and equally distributed within different combinations of *C* and *NC Info* conditions.



RESULTS and DISCUSSION

The ANOVA on correct RTs, with *Information* (*C Info* vs. *NC Info*) as between subjects factor and *Stimulus Position* (*left* vs. *right*) and *Response Position* (*left* vs. *right*) as within subjects factors, yielded the main effect of *Information* (p<0.001). Performances were better when G and R were spatially compatible [*C Info*] than when they were spatially incompatible [*NC Info*] (682 vs. 780 ms), indicating a Spatial G-R Compatibility effect.
A significant three-way interaction between *Information*, *Stimulus Position*, and *Response Position* (p<0.001) and Post-hoc tests (Newman-Keuls) showed a Simon effect in *C Info* conditions and an inverted Simon effect in *NC Info* conditions.



We found not only a G-R effect, but also an S-G effect. Indeed, *NC Info* performances were better when S and G, but not S and R, were spatially compatible than when S and G, but not S and R, were spatially incompatible.
Therefore, when S-R spatial information is task-irrelevant, spatial compatibility between stimulus eliciting a goal-directed motor pattern and intended action goal prevails over spatial S-R compatibility and affects performance by inverting Simon effect.

CONCLUSIONS

Spatial processing determines action's representation, containing intentions, perceptual effects, and goals to attain. Our study shows that spatial correspondence between stimulus, response and intended action goal affects behaviour. Indeed, we proved that a spatially incompatible practicing affects spatial S-R relations during a subsequent virtual navigation. Moreover, by simulating virtual Spatial S-R Compatibility and Simon tasks, we found spatial compatibility effects between stimulus-related action goals and manual responses (G-R effect), and between visual stimuli and related action goals (S-G effect). Therefore, if spatial features of stimuli are action-relevant, then responses prevail over goals in determining behaviour; instead, if spatial features of stimuli are action-irrelevant, then goals prevail over responses.
People make use of spatial relations between movements and movement-contingent sensory events both to formulate their intended action goals and to select the appropriate motor pattern to perform. According to associative learning theory, suggesting that in the cognitive system associative representations of intended goals guide actions (Hommel, 1993; Kunde, 2001; Ansorge, 2002), we conclude that actions are controlled by anticipating their effects.

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