# Practical ergonomics recommendations for the use of auditory and visual signals for improving system performance

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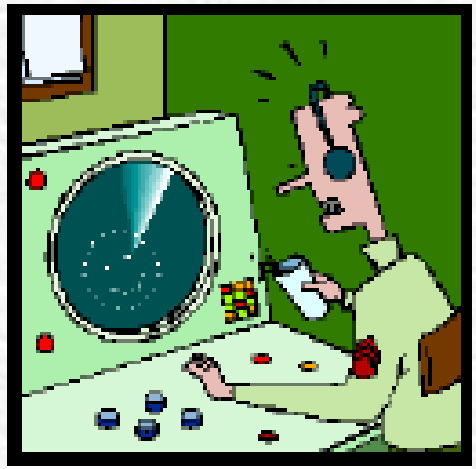
# Background

Displays and controls are the fundamental means of communication for people interacting with machines and equipment.

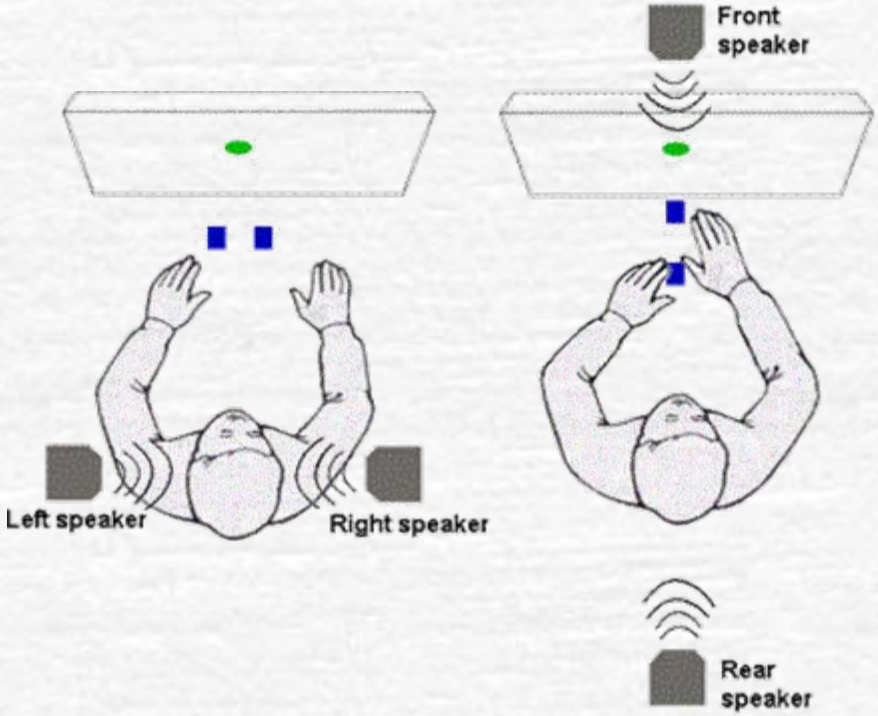
It is important to understand the interactions and relationships between display and control devices in control consoles because effective human-machine interfaces are obviously advantageous for improving human performance and overall system safety.



# Experiments

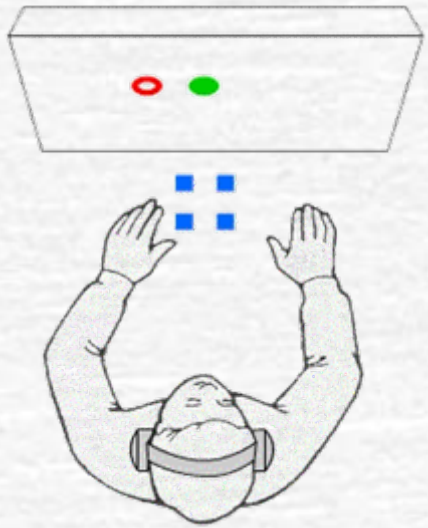
## Experiment 1

Spatial stimulus-response (S-R) compatibility effect of auditory signal on Transverse and Longitudinal orientations




## Experiment 2

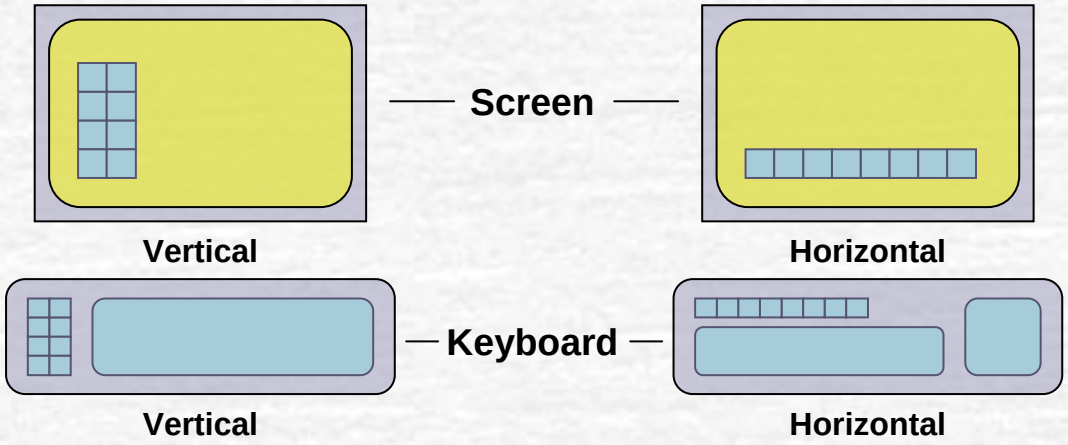
Spatial S-R compatibility effect of Visual and Auditory signals on transversely and longitudinally oriented axes



# Literature review

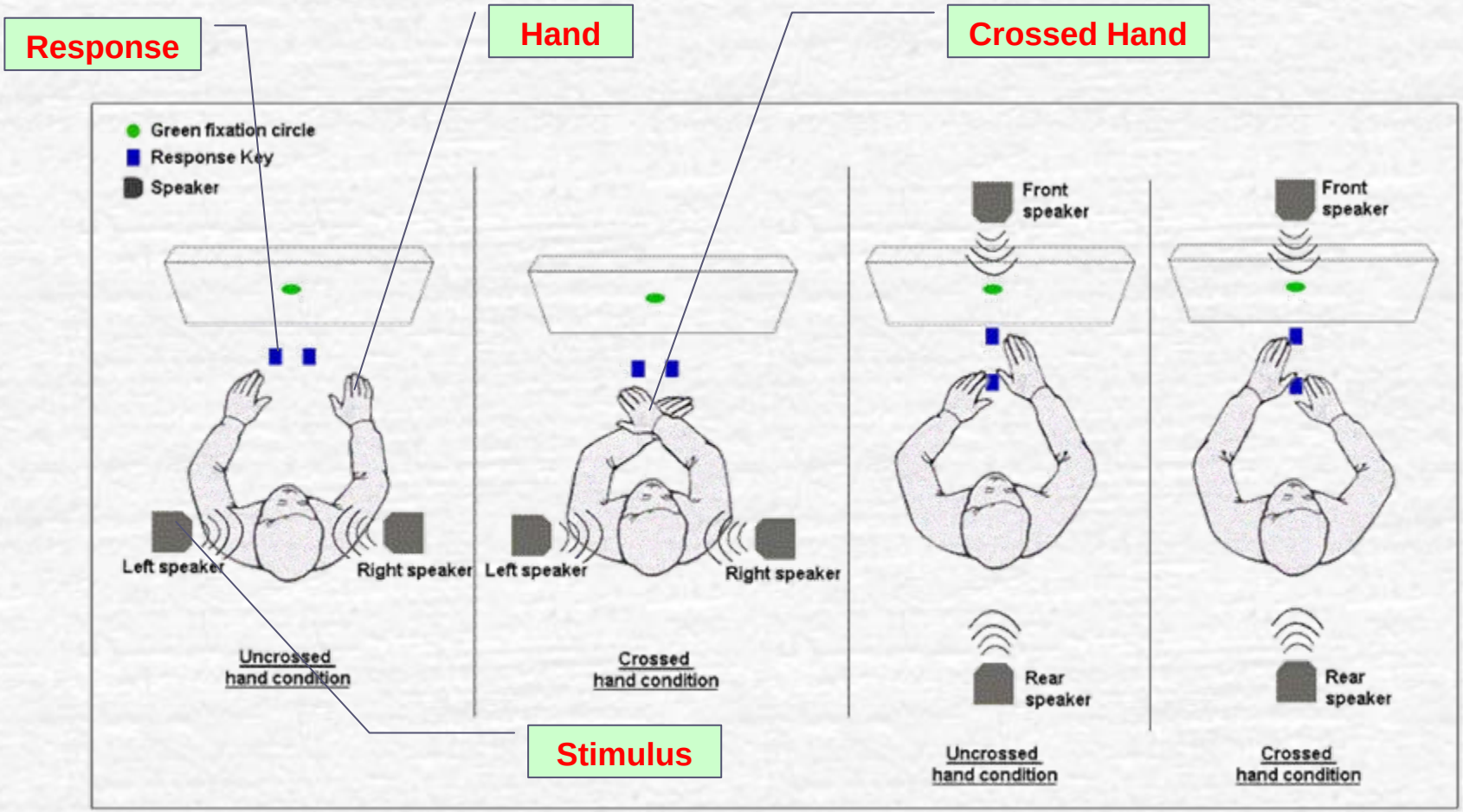
In design of human-machine interfaces, it is necessary to understand how the display stimulus features interact with the attributes of the response set.

"Spatial S-R compatibility" was introduced by Fitts and his co-workers (Fitts and Seeger, 1953), which refers to situations where selection of a response is directly related to the position of a stimulus



# Experiment 1

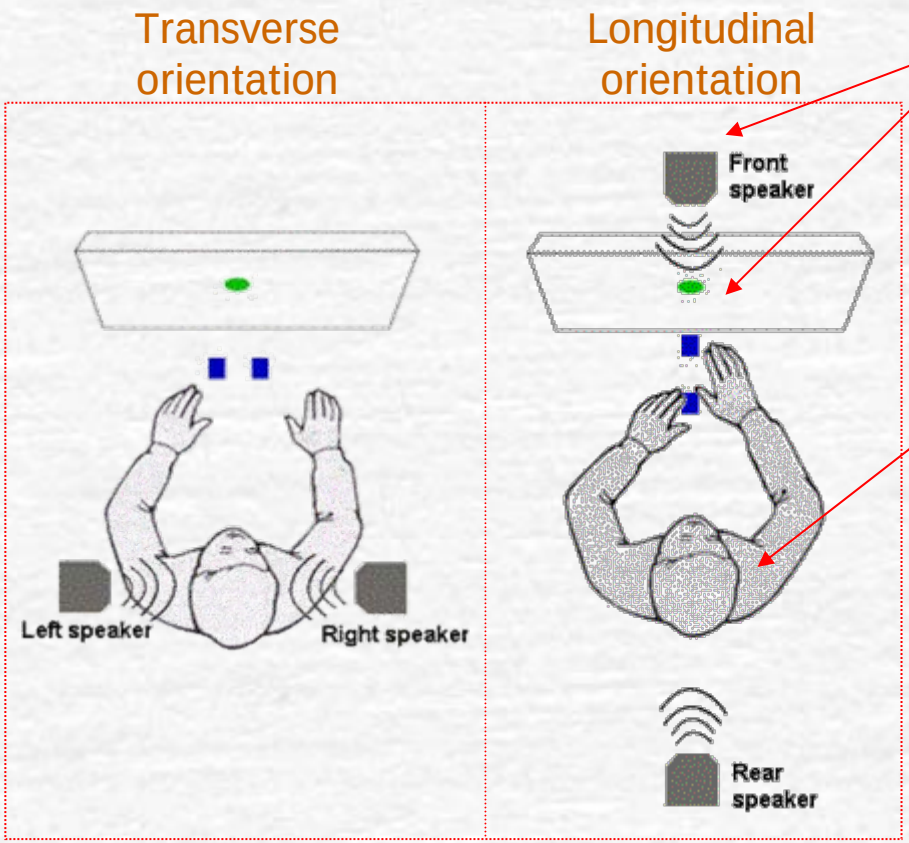
**Auditory S-R compatibility effect on Transverse and Longitudinal orientations**



# Why Exp1?

- Stimulus-response correspondence, stimulus-hand correspondence or both of them, contribute to the spatial S-R compatibility.
- The perception of auditory signal could be difficult when the sound source being transmitted is positioned in straight ahead or behind the subject.
- The effect of auditory S-R compatibility was tested on longitudinal orientation to investigate the degree of difficulty the subject undergo in reacting to the longitudinal stimulus orientation.

# Methodology of Exp1




## Apparatus and Stimulus

- Two speakers were located on the left and right side (transverse) or front and rear side (longitudinal).

## Subject

- 36 Chinese right-handers
- Age: 20-24
- Assessed to have normal hearing and vision abilities.

## Procedure

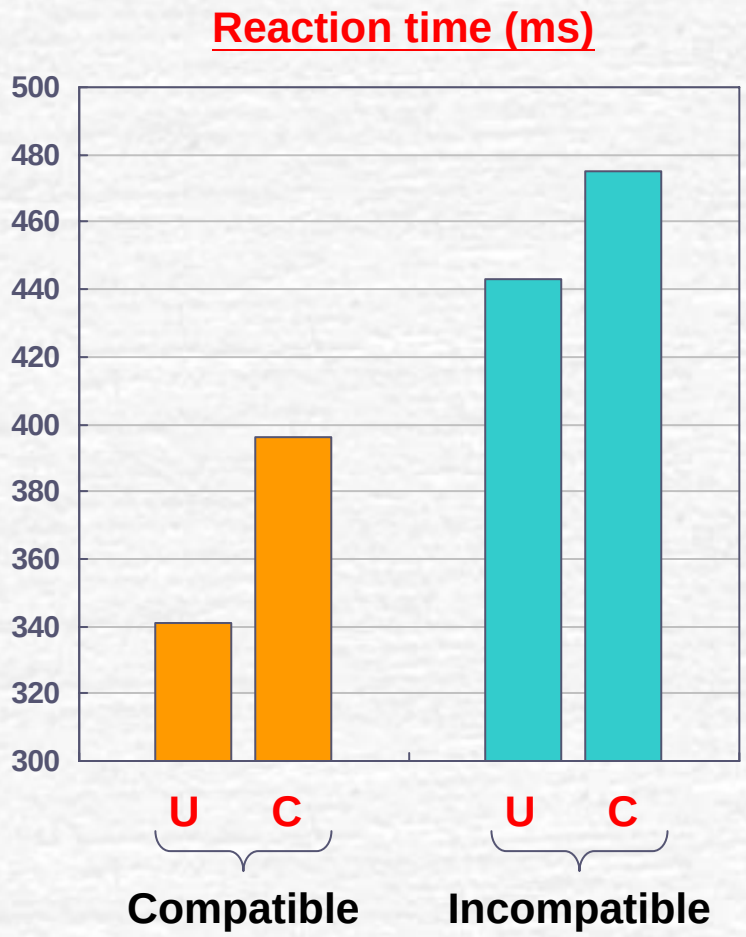
- Compatible pairing: e.g. Right key > Right signal; Front key > Front signal
- Incompatible paring: e.g. Right key > Left signal; Front key > Rear signal
- To respond as fast and accurate as subjects could.

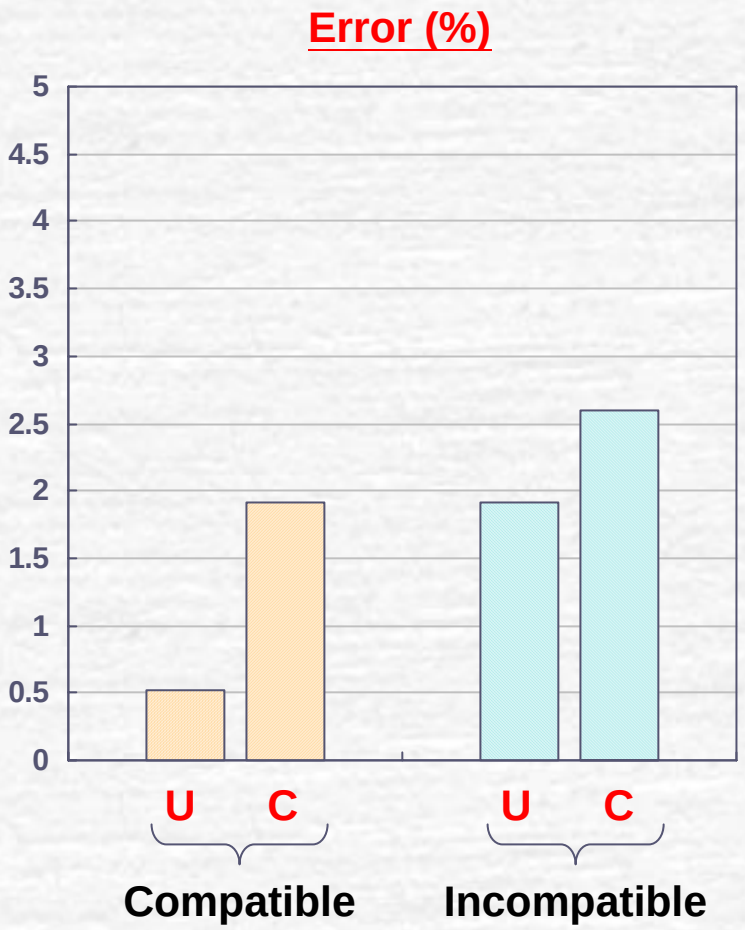
# Result of Exp1 (Transverse)

| S-R Mapping (Transverse) | Hand Condition | Mean RT | Average |
|---|---|---|---|
| Compatible | Uncrossed | 341 ms | 368 ms |
| | Crossed | 396 ms | |
| Incompatible | Uncrossed | 443 ms | 458 ms |
| | Crossed | 475 ms | |

| S-R Mapping (Transverse) | Hand Condition | Mean Error % | Average |
|---|---|---|---|
| Compatible | Uncrossed | 0.52% | 368 ms |
| | Crossed | 1.91% | |
| Incompatible | Uncrossed | 1.91% | 458 ms |
| | Crossed | 2.60% | |

# Result of Exp1 (Transverse)

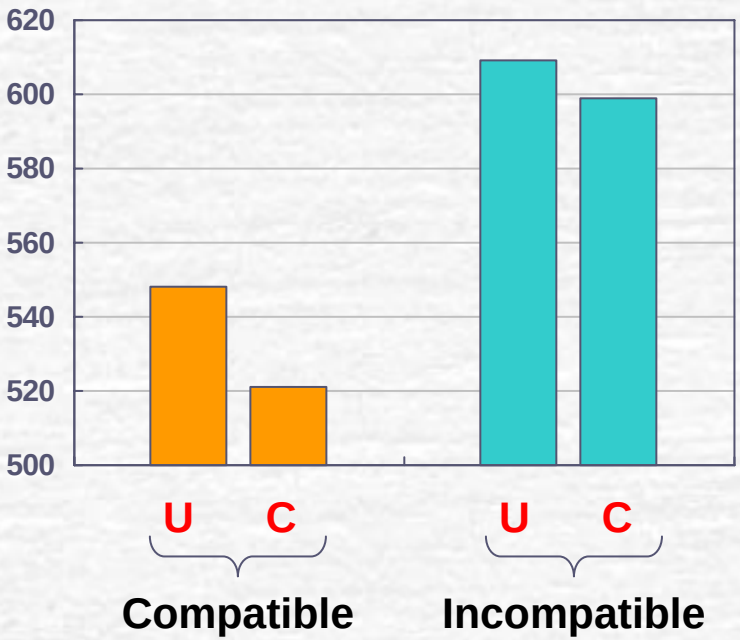


# Result of Exp1 (Longitudinal)

| S-R Mapping (Longitudinal) | Hand Condition | Mean RT | Average |
|---|---|---|---|
| Compatible | Uncrossed | 548 ms | 535 ms |
| | Crossed | 521 ms | |
| Incompatible | Uncrossed | 609 ms | 604 ms |
| | Crossed | 599 ms | |

Reaction time (ms)



# Discussion of Exp1

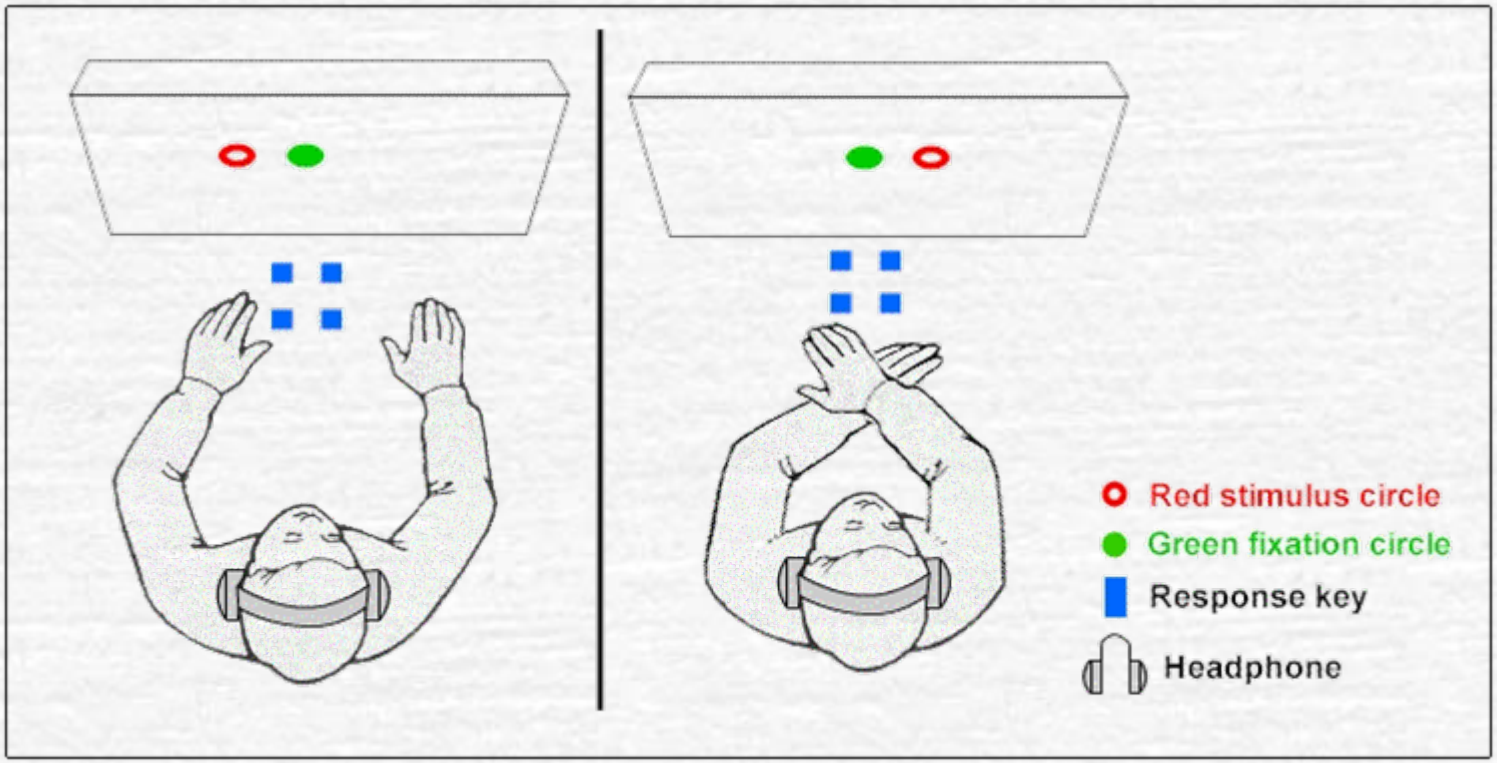
- Salient auditory S-R compatibility effect was found in both the transverse and longitudinal orientations.
- Shorter reaction time and lower error percentage were noticed in transverse orientation than in longitudinal one. (412ms vs. 569ms) (1.7% vs. 10.3%)
- Subjects responded faster and more accurately in the uncrossed hand condition than in crossed hand condition in transverse orientation.
  (391ms vs. 434ms) (1.22% vs. 2.26%)
- Dominant right hand was faster than non-dominant left hand in reaction.
  (406ms vs. 418ms)

# Conclusion of Exp1

- There is no contribution of stimulus-hand correspondence in this simple auditory two-choice reaction task.
- The mismatch of spatial codes reduces not only speed but also accuracy.
- The longitudinal arrangement of auditory stimulus was strongly discouraged in the control console due to the difficulty in signal localization.
- It is suggested that response by normal hand posture is conducive to better performance.

# Experiment 2

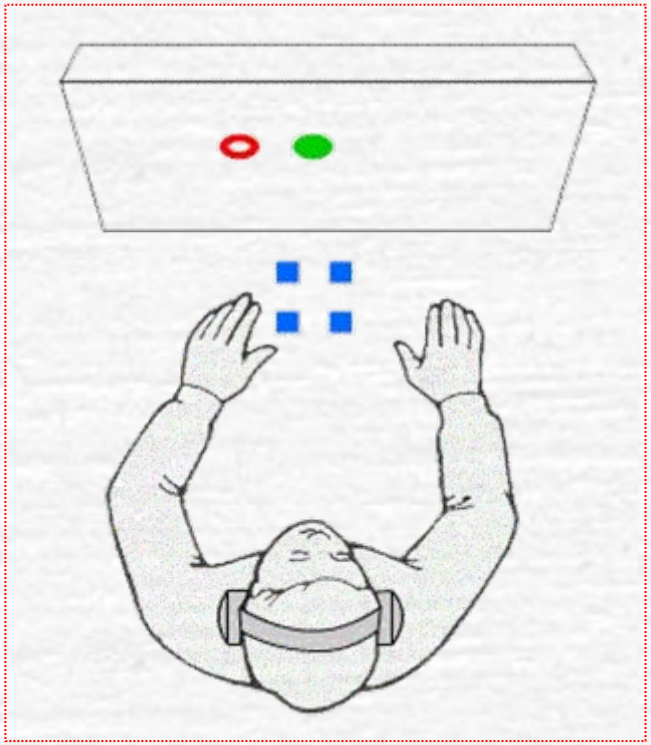
**Spatial S-R compatibility of Visual and Auditory stimuli on transverse and longitudinal oriented axes**



# Why Exp2?

- Most of the previous studies on spatial S-R compatibility in various stimulus arrangements are limited to single stimulus display.
- The investigation of visual-auditory stimulus interaction is rarely found in the context of spatial compatibility.
- Human performance in the presentation of visual and auditory stimuli in the context of spatial S-R compatibility.

# Methodology of Exp2



## Apparatus and Stimulus

- 2 signal types: Visual and Auditory signals
- 4 response keys: FL, FR, RL & RR

## Subject

- 20 Chinese right-handers
- Age: 25-36
- Assessed to have normal hearing and vision abilities.

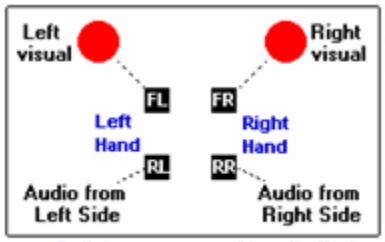
## Procedure

- Either a visual circle or a tone was presented randomly.
- Green circle provides both a warning signal and a fixation point.
- Pressed the appropriate key after the detection of stimulus (S-R mappings).
- No feedback on speed and accuracy.

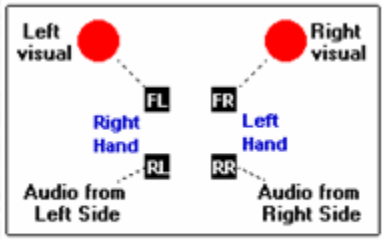
# Methodology of Exp2 (cont.)

## FOUR spatial mapping conditions

**1**

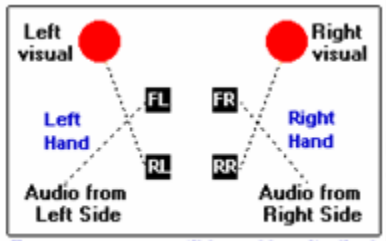



Both transverse and longitudinal compatible uncrossed

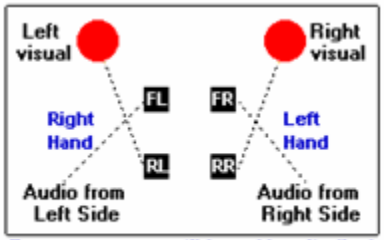



Both transverse and longitudinal compatible crossed

**2**

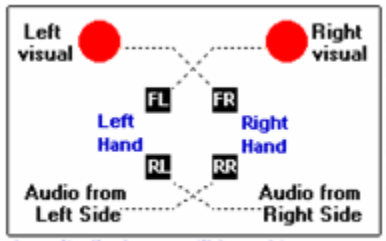



Transverse compatible and longitudinal incompatible uncrossed

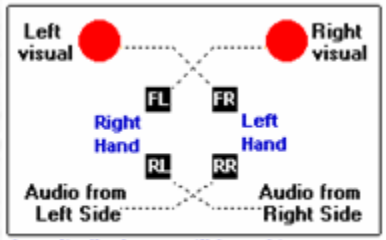



Transverse compatible and longitudinal incompatible crossed

**3**

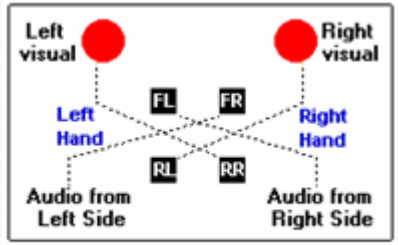



Longitudinal compatible and transverse incompatible uncrossed

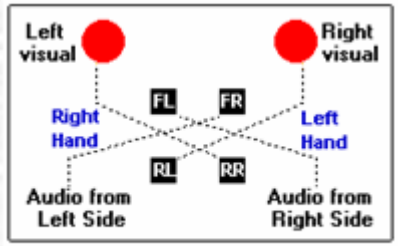



Longitudinal compatible and transverse incompatible crossed

**4**



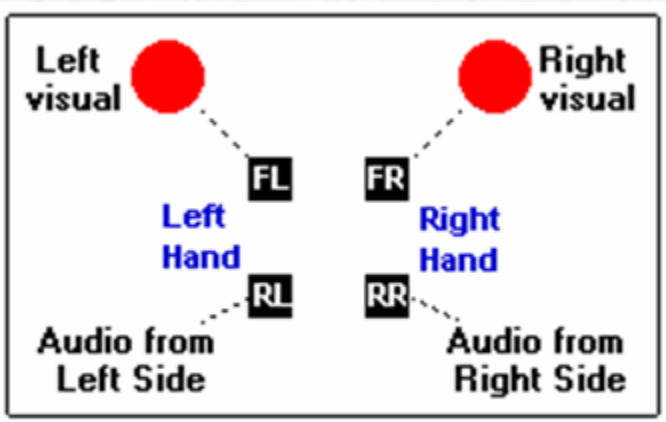

Both transverse and longitudinal incompatible uncrossed



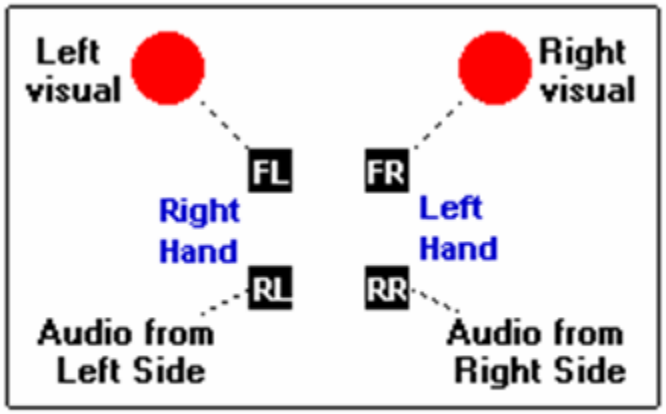

Both transverse and longitudinal incompatible uncrossed

# Methodology of Exp2 (cont.)

**1** - **B**oth the transverse and longitudinal orientations are **C**ompatible (**BC**)




Both transverse and longitudinal compatible uncrossed




Both transverse and longitudinal compatible crossed

Front-Left (FL) key to the left visual signal

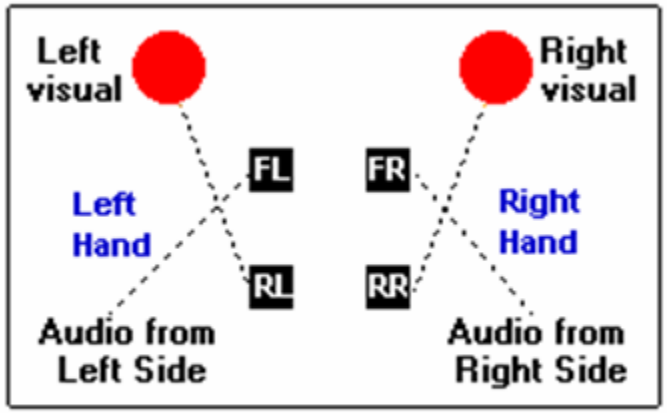
Front-Right (FR) key to the right visual signal

Rear-Left (RL) key to the left auditory signal

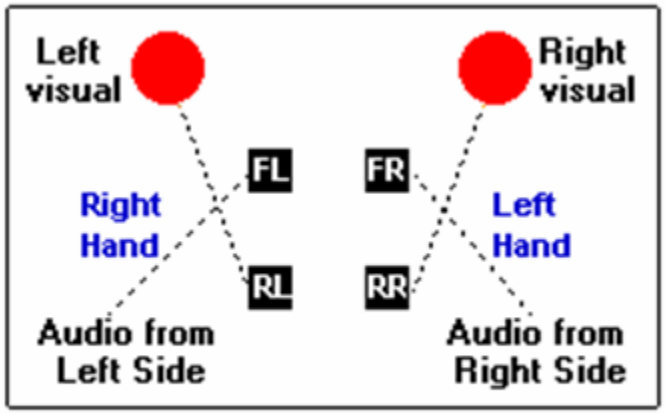
Rear-Right (RR) key to the right auditory signal

# Methodology of Exp2 (cont.)

## 2 - Transverse Compatible and longitudinal incompatible condition (TC)




Transverse compatible and longitudinal incompatible uncrossed




Transverse compatible and longitudinal incompatible crossed

Front-Left (FL) key to the left auditory signal

Front-Right (FR) key to the right auditory signal

Rear-Left (RL) key to the left visual signal

Rear-Right (RR) key to the right visual signal

# Methodology of Exp2 (cont.)

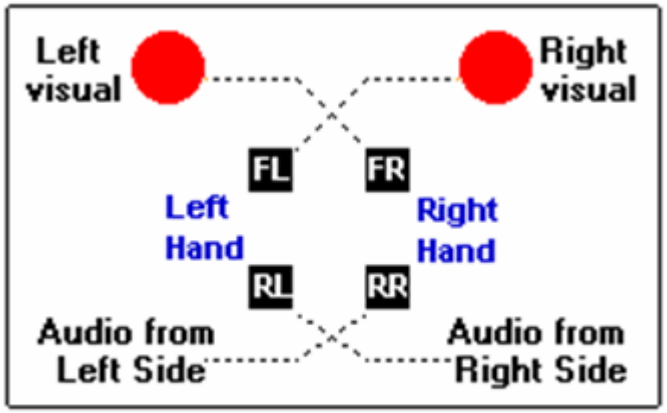
**3** - **L**ongitudinal **C**ompatible and transverse incompatible condition (**LC**)

Front-Left (FL) key to the right visual signal

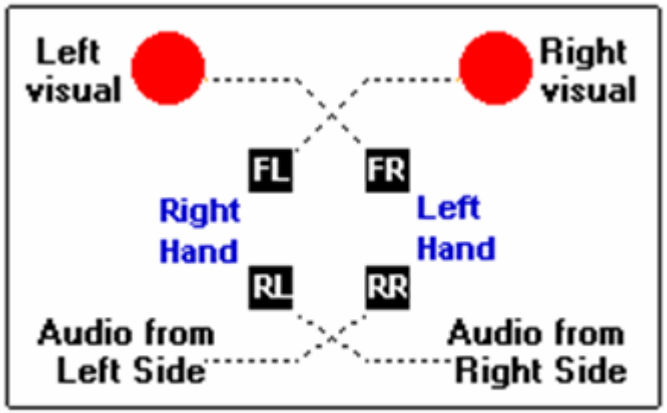
Front-Right (FR) key to the left visual signal

Rear-Left (RL) key to the right auditory signal

Rear-Right (RR) key to the left auditory signal




Longitudinal compatible and transverse incompatible uncrossed




Longitudinal compatible and transverse incompatible crossed

# Methodology of Exp2 (cont.)

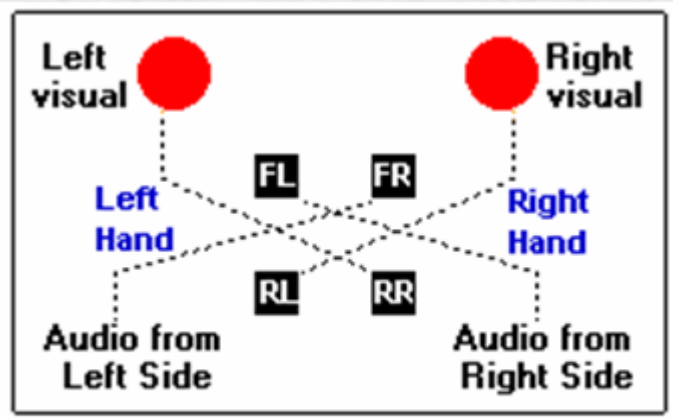
## 4 – **B**oth transverse and longitudinal orientations are **I**ncompatible (**BI**)

Front-Left (FL) key to the right auditory signal

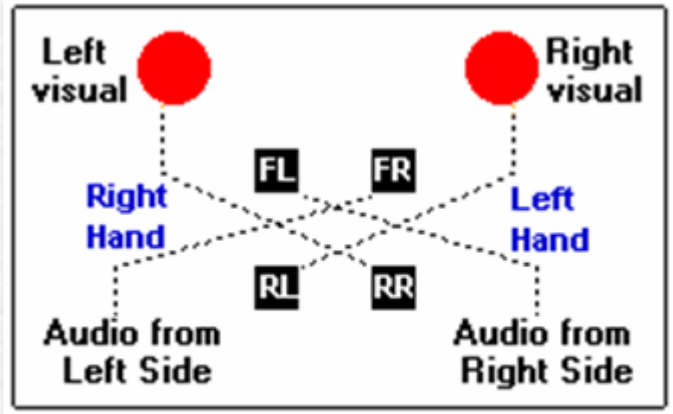
Front-Right (FR) key to the left auditory signal

Rear-Left (RL) key to the right visual signal

Rear-Right (RR) key to the left visual signal



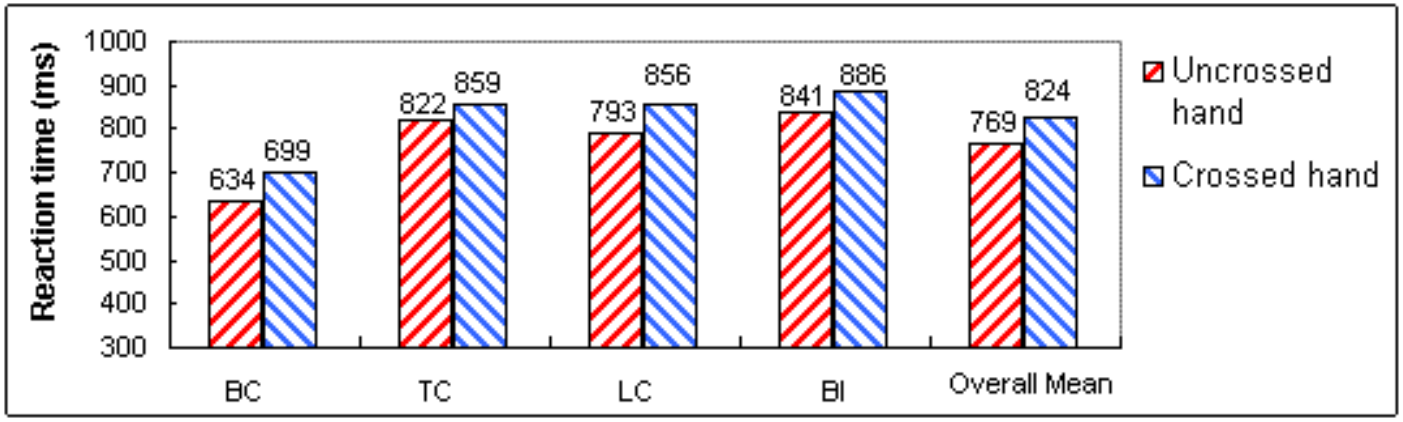

Both transverse and longitudinal incompatible uncrossed




Both transverse and longitudinal incompatible uncrossed

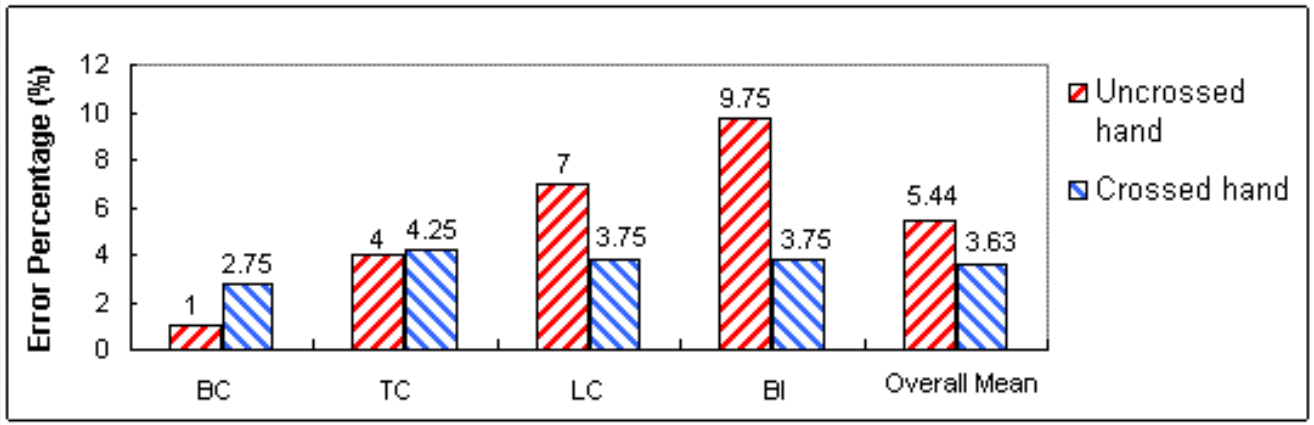
# Result of Exp2 (Mean RT)

| S-R Mapping | Hand Condition | Mean RT | Average |
|---|---|---|---|
| Both transverse and longitudinal Compatible (BC) | Uncrossed | 634 ms | 666 |
| | Crossed | 699 ms | |
| Transverse Compatible and longitudinal incompatible (TC) | Uncrossed | 822 ms | 840 |
| | Crossed | 859 ms | |
| Longitudinal Compatible and transverse incompatible (LC) | Uncrossed | 793 ms | 825 |
| | Crossed | 856 ms | |
| Both transverse and longitudinal Incompatible (BI) | Uncrossed | 841 ms | 864 |
| | Crossed | 886 ms | |



# Result of Exp2 (Error %)

| S-R Mapping | Hand Condition | Error % | Average |
|---|---|---|---|
| Both transverse and longitudinal Compatible (BC) | Uncrossed | 1.00% | 1.88% |
| | Crossed | 2.75% | |
| Transverse Compatible and longitudinal incompatible (TC) | Uncrossed | 4.00% | 4.13% |
| | Crossed | 4.25% | |
| Longitudinal Compatible and transverse incompatible (LC) | Uncrossed | 7.00% | 5.38% |
| | Crossed | 3.75% | |
| Both transverse and longitudinal Incompatible (BI) | Uncrossed | 9.75% | 6.75% |
| | Crossed | 3.75% | |



# Discussion of Exp2

- Salient spatial S-R compatibility was found which revealed that visual-auditory information could be merged spatially.
- Responses in uncrossed hand condition were found to be significantly faster and more accurate than in the crossed hand condition in BC and TC mappings.
- In LC and BI mappings, responses in uncrossed hand condition were found less accurate than in crossed hand condition.
  (LC: 7% vs. 3.75%) (BI: 9.75% vs. 3.75%)
- LC-Crossed and BI-Crossed conditions are both stimulus-response incompatible but stimulus-hand compatible mapping conditions.

# Conclusion of Exp2

- The reaction time to a stimulus depends on the spatial relationship between the stimulus and response sets.
- Stimulus-hand (S-H) correspondence seems to contribute to S-R compatibility.
- It is believed that when the spatial code recognition is difficult (LC & BI), coding in terms of the anatomical code (hands) may come to play.
- Visual-Auditory information could be matched spatially with similar magnitude to that found in simple S-R mappings.

# Useful ergonomics design recommendations for human machine interfaces

- Auditory signals for soliciting specific responses or directional attention should not be positioned in a longitudinal orientation with respect to the person.
- Signals placed in a transverse orientation will produce quicker and more accurate responses.
- For faster reaction times, auditory signals should be positioned on the right hand side of right-handed operators.

# Useful ergonomics design recommendations for human machine interfaces

- The relative positions of signals should be compatible with both the response key positions and the hand positions of the operators.
- Control-display configurations with compatibility designed in both the longitudinal and transverse orientations lead to the best performance. If compatibility can only be built in one orientation, the transverse orientation should be selected.

# Useful ergonomics design recommendations for human machine interfaces

- The layout of response keys on control consoles should be compatible with the hand positions of the operators. Designs that require crossing the hands to respond should not be used.
- If operators are required to respond using front and rear keys on a horizontal plane, the right hand should be assigned to the rear key and left hand to front key.
- For faster reaction times, a three second fore period warning should be given before signal presentation to alert the operators.

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# The End
# Thank you

Department of Manufacturing Engineering and Engineering Management