

Factors Affecting Speed and Accuracy of Response Selection in Operational Environments

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MURI Project:

Training Knowledge and Skills for the Networked Battlefield

MURI

Multidisciplinary University Research Initiative

Collaborators

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- C. Gonzalez - Carnegie Mellon U.

MURI Project:

Training Knowledge and Skills for the Networked Battlefield

Objective

“Construct a theoretical and empirical framework that can account for and make accurate predictions about the effectiveness of different training methods”

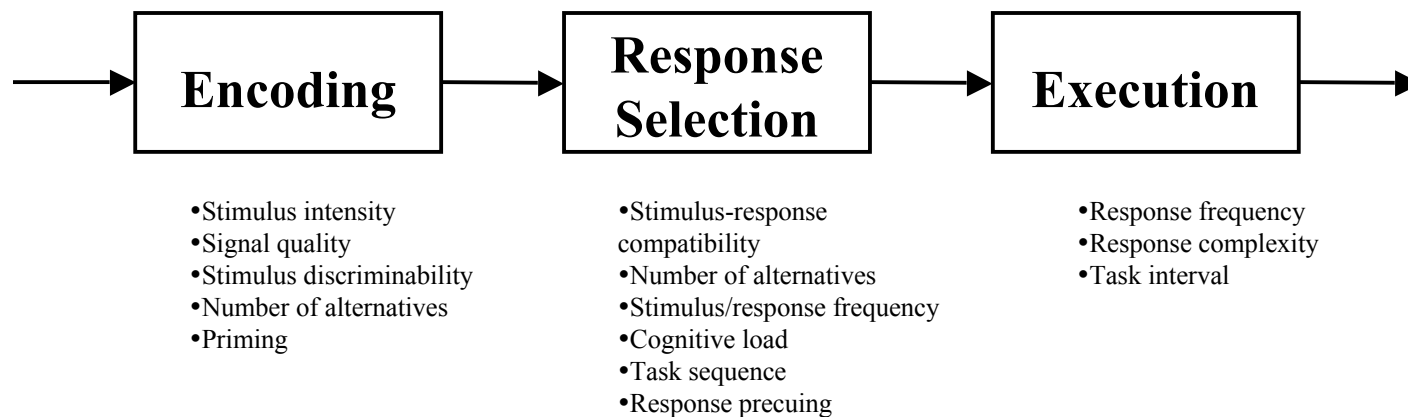
(<http://psych.colorado.edu/~ahealy/MuriFrame.htm>)

Project components:

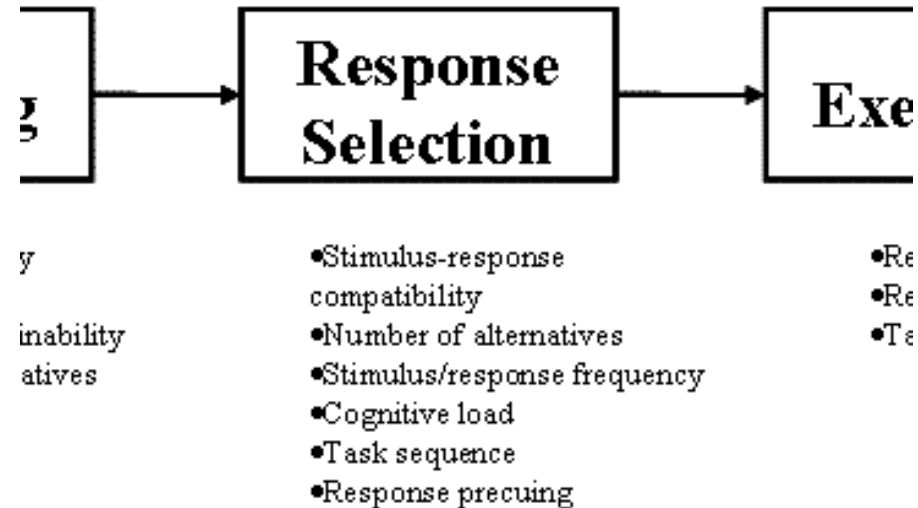
- (a) Experimental investigations of components and principles for training of individuals and teams**
- (b) Development of a taxonomy for training programs
- (c) ACT-R and IMPRINT modeling of training efficiency

Information Processing:

A framework for analyzing human performance and its relationship with environmental factors



Factors Affecting Response Selection:



- Speed and accuracy of performance depends heavily on response-selection (RS) skills.
- Training benefits RS skills the most.

Response-Selection Issue in Interface Design:

Compatibility Principle

Response selection is faster and more accurate when an interface is compatible with natural response tendencies

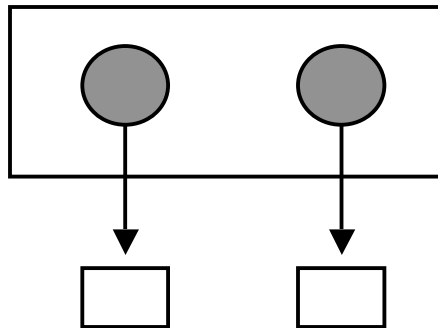
“The topic of things that go together – alphabets, S-R ensembles, optimum coding, S-R compatibility, and related effects – is central... not only to the interests of the cognitive psychologist but also to the repertoire of expertise out of which the human-factors specialist contributes to the design and use of human-machine systems” (Alluisi & Warm, 1990)

* Incompatible interfaces cause human-induced accidents

Experimental Task Variants:

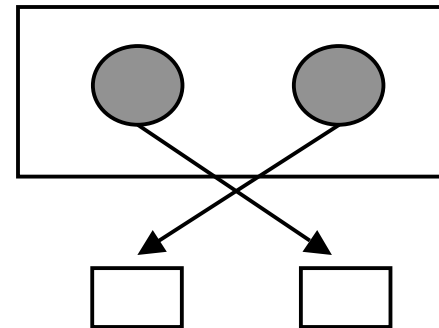
Task-relevant compatibility

- SRC task:



Compatible mapping

LEFT signal → LEFT button
RIGHT signal → RIGHT button



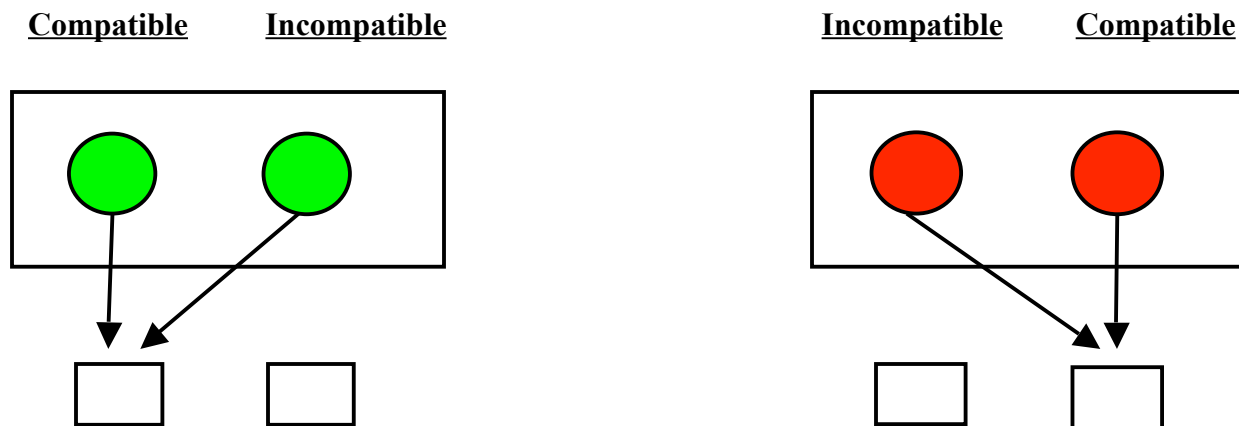
Incompatible mapping

LEFT signal → RIGHT button
RIGHT signal → LEFT button

Experimental Task Variants:

Task-irrelevant compatibility

- Simon task:



GREEN signal → LEFT button

RED signal → RIGHT button

“Spatial location is not relevant to performing the task”

Compatibility Effects & Task Training

May, 2008

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CID workshop

Compatibility Effects & Task Training:

Task-relevant SRC case

Fitts & Seeger (1953)

- 32 days of practice (48 trials for each day) with an 8-choice task reduced the SRC effect.
- Performance reached an asymptotic level in 15 days, but the effect was not eliminated.

Dutta & Proctor (1992)

- 8 days of practice (300 trials for each day) with 2- or 4-choice task, with an asymptote-level reached in 4 days, but the SRC effect was not eliminated.

***“Practice strengthens learned S-R associations
but does not replace previously established
associations”***

Compatibility Effects & Task Training:

Task-irrelevant SRC case

Proctor & Lu (1999)

- 3 sessions of practice (600 trials for each session) with the Simon task did not eliminate the benefit for spatial correspondence.

→ **However, 3 sessions of practice with an *incompatible spatial mapping* reversed the Simon effect in the 4th session.**

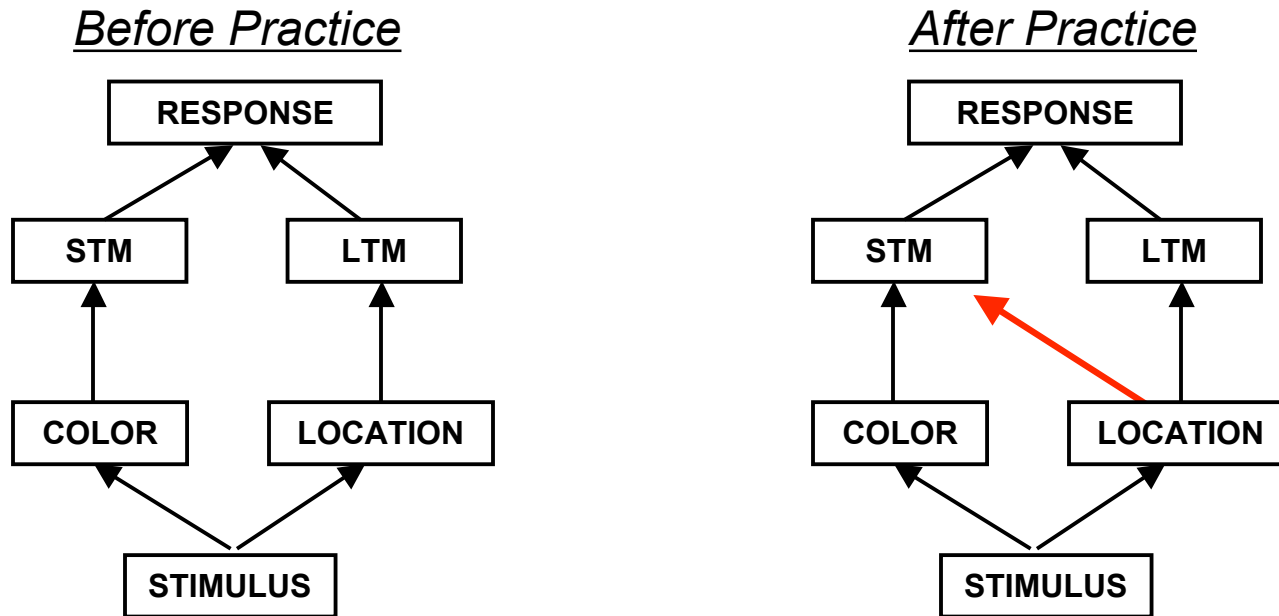
Tagliabue et al. (2000)

- 1 session of practice (72 trials) with the incompatible mapping eliminated the Simon effect.

Compatibility Effects & Task Training:

Connectionist model of the Simon effect

Task-defined S-R mapping → STM-link
Task-irrelevant S-R mapping → LTM-link



Practice = New STM-link

Compatibility Effects & Task Training:

Training specificity principle

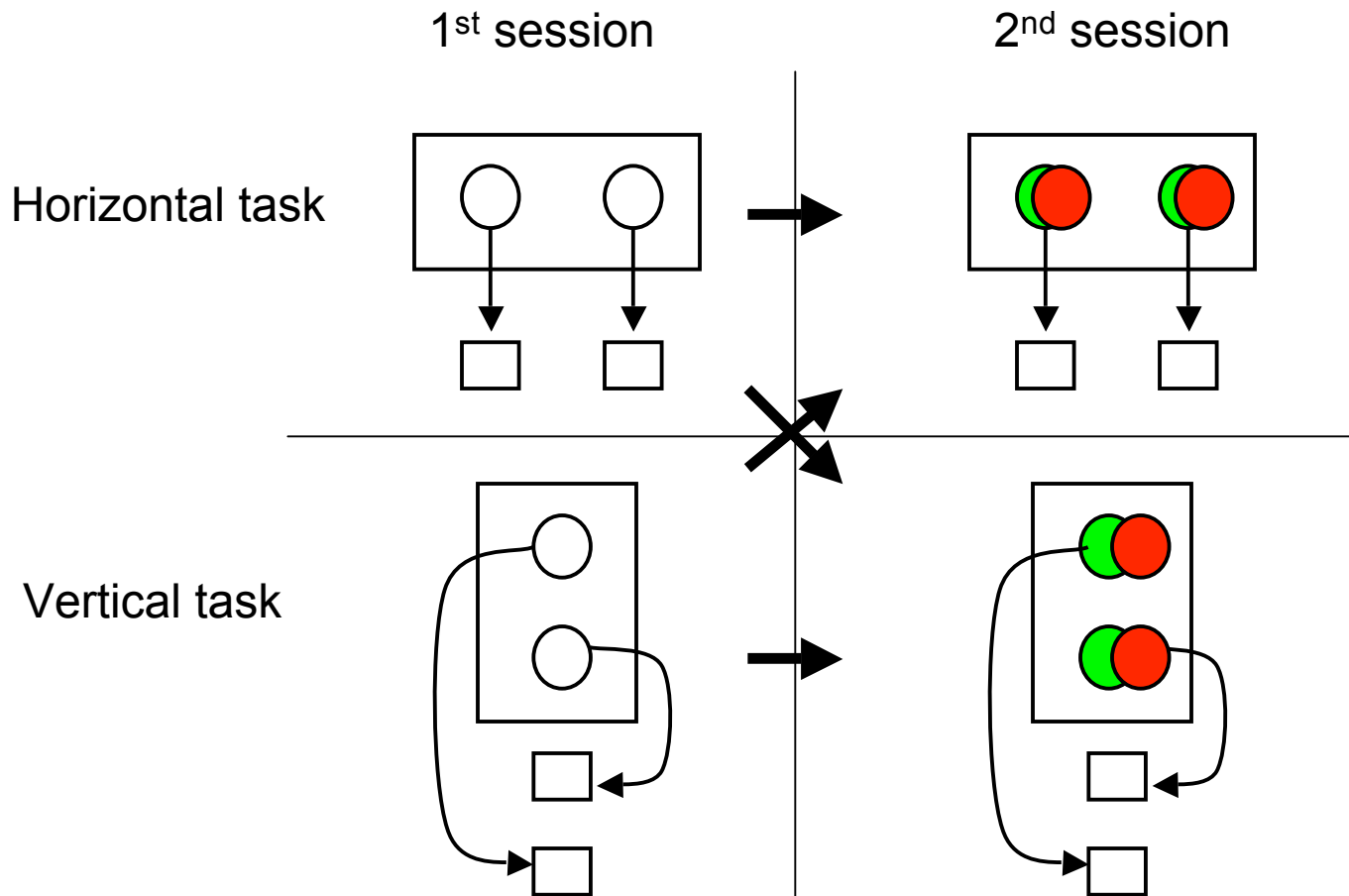
Manifestation of skills is specific to the trained context

Contextual factors in perceptual-motor skills

- a. Spatial dimension
- b. Sensory modality
- c. Stimulus codes
- d. Response codes

Compatibility Effects & Task Training:

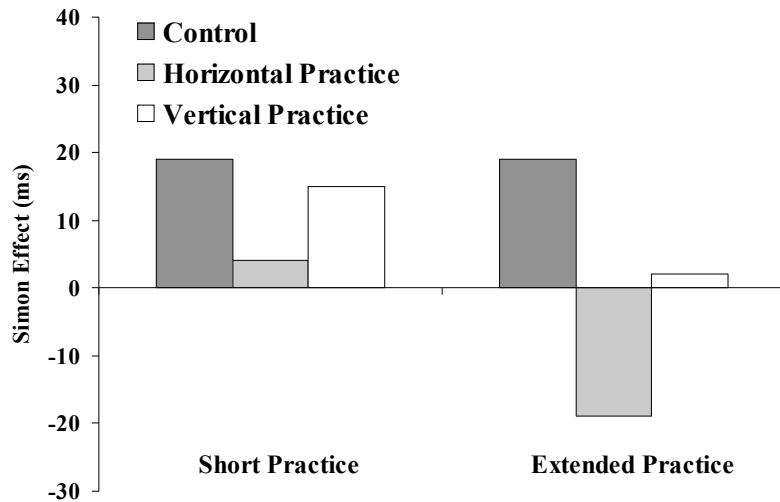
a) Transfer across spatial dimensions



Compatibility Effects & Task Training:

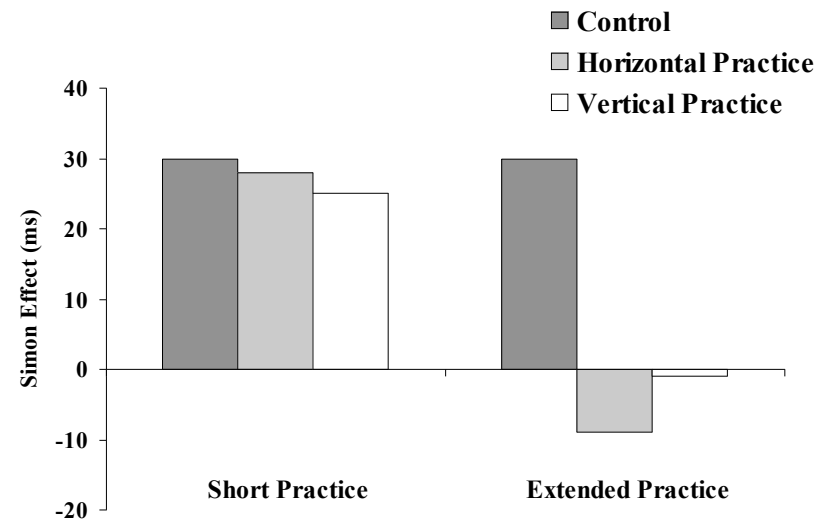
Horizontal Simon

- Transfer was significantly smaller when the spatial dimension differed.
- Between-dimension transfer appeared after extended practice.



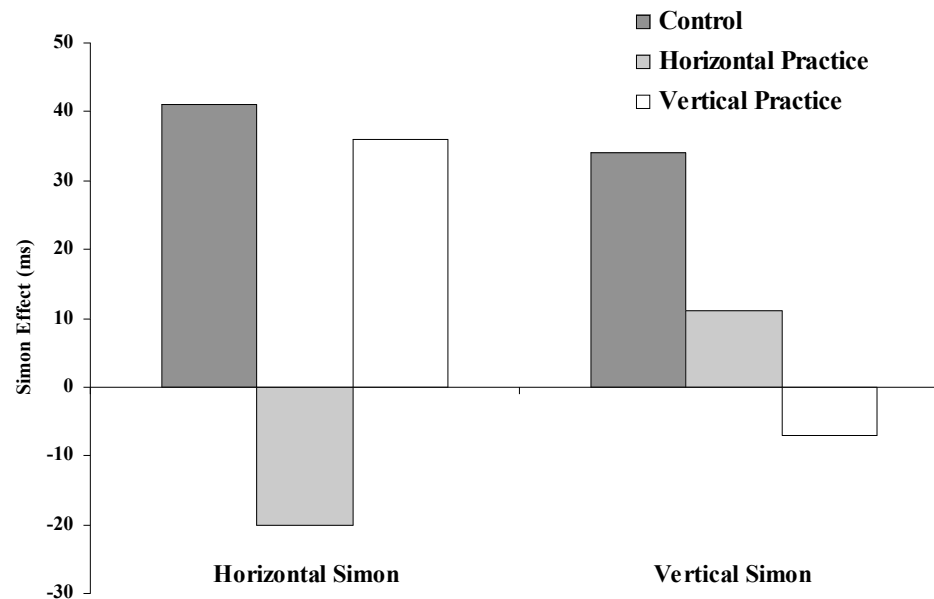
Vertical Simon

- Transfer occurred only after extended practice (within- and between-dimensions).
- Specificity of training was not evident.



Compatibility Effects & Task Training:

- With auditory stimuli (extended practice), the specificity of training dimension was also apparent for the horizontal task.
- The specificity was weaker but manifested for the vertical task, too.



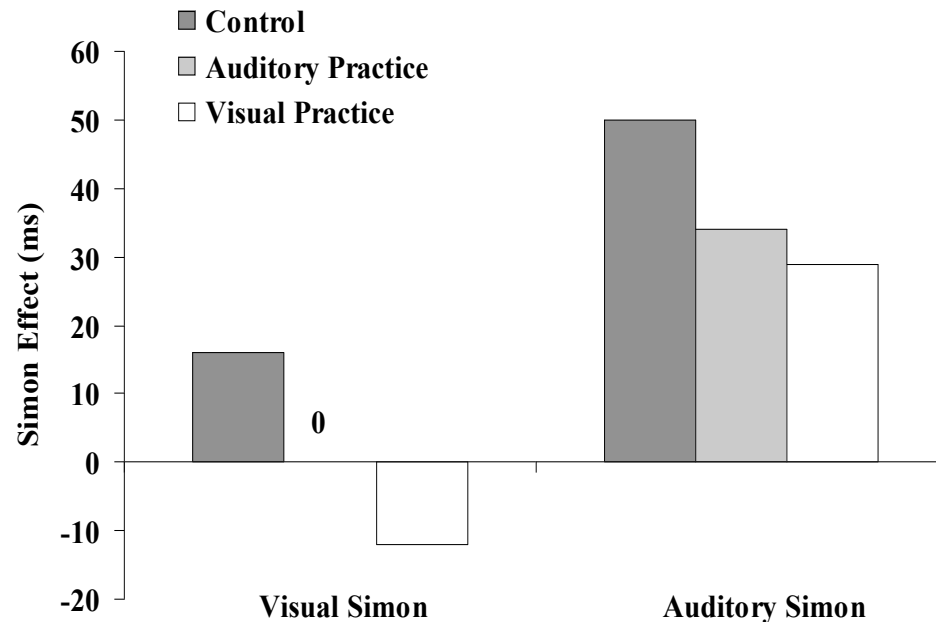
Compatibility Effects & Task Training:

b) Transfer across sensory modality

- The Simon effect was larger for auditory stimuli than visual stimuli.

- Auditory stimuli produced a smaller transfer effect than did visual stimuli.

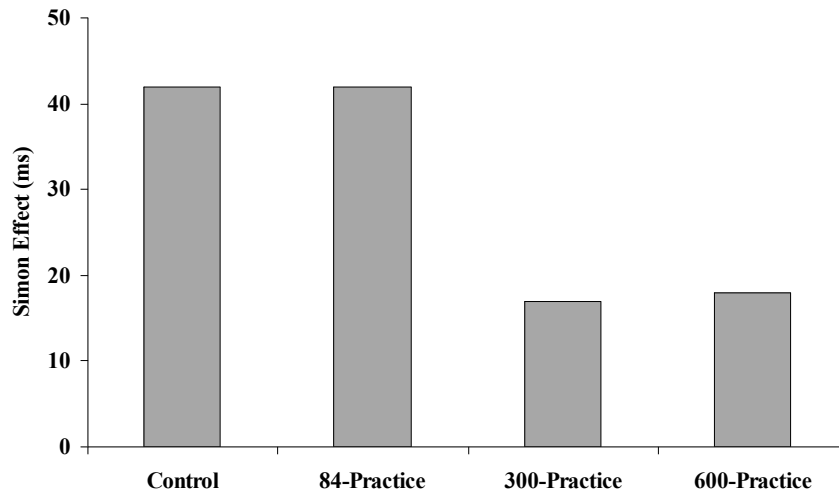
- For the visual Simon task, specificity of stimulus modality is evident, though transfer did occur after practice with auditory stimuli.



Compatibility Effects & Task Training:

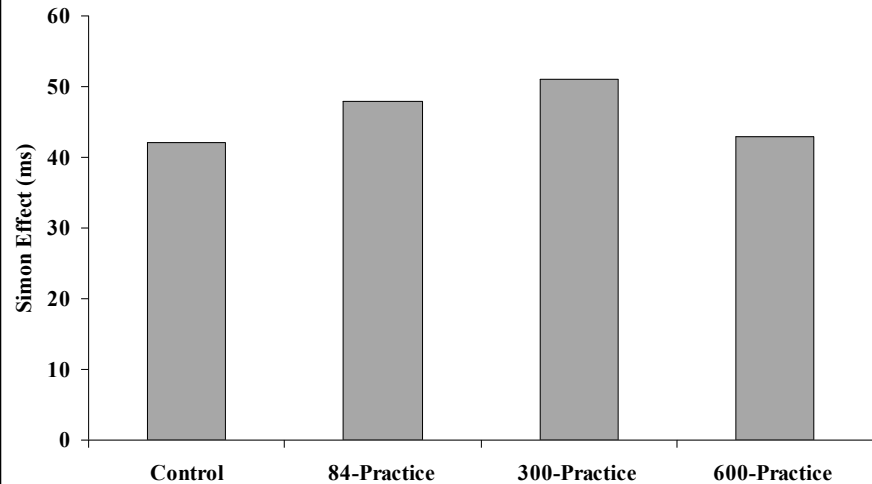
Auditory Practice – Auditory Transfer

With auditory modality, extended practice is required for transfer to occur.



Visual Practice – Auditory Transfer

However, extended practice did not yield transfer when visual modality was used for the practice session.

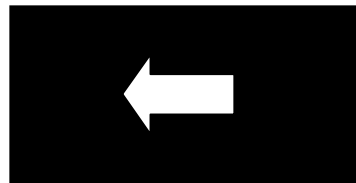
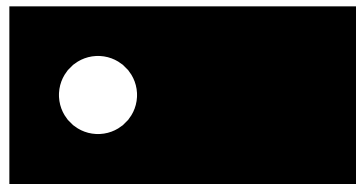


Compatibility Effects & Task Training:

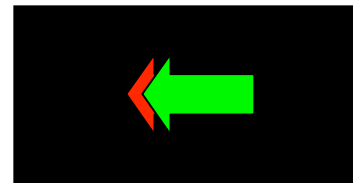
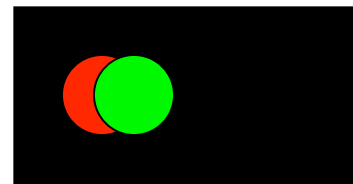
c) Stimulus mode

3 ways to convey spatial information

1st session

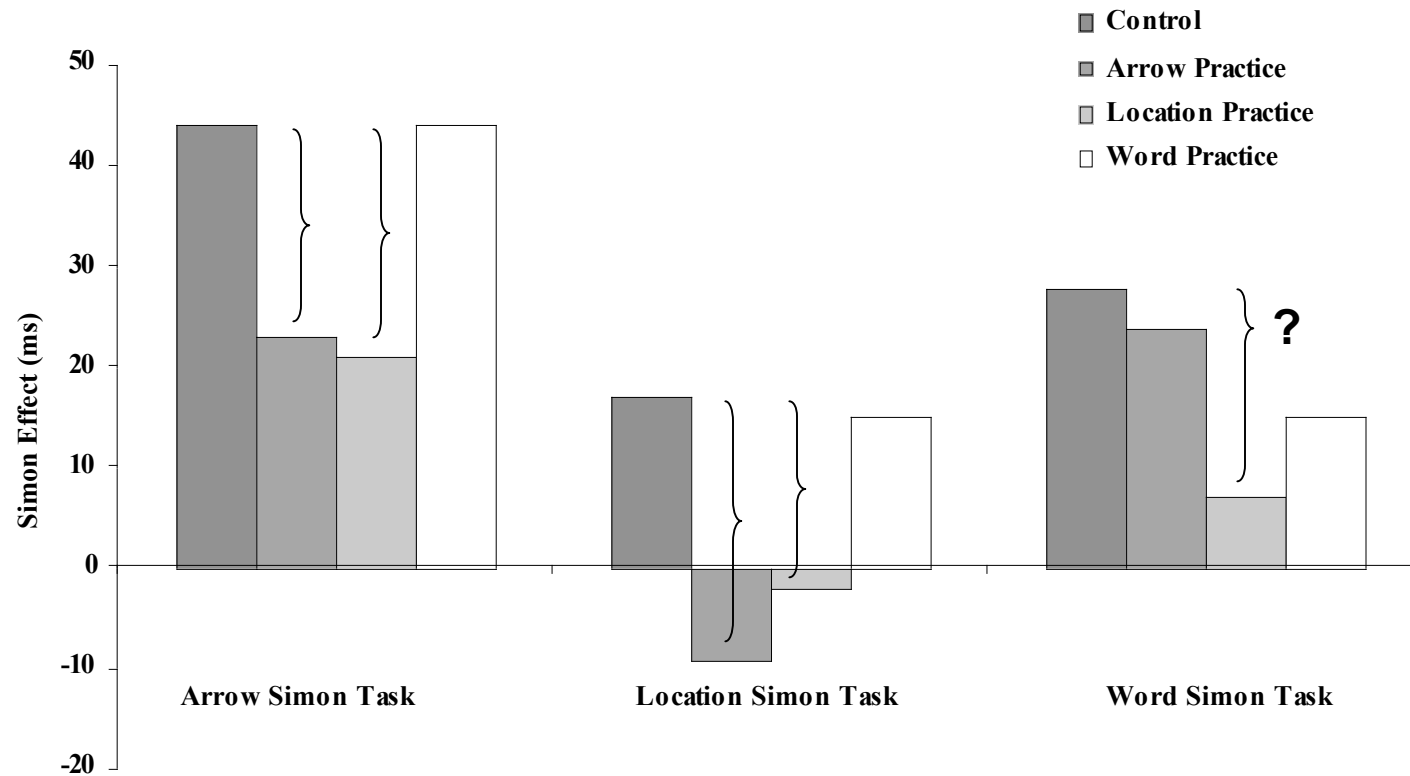


2nd session



Compatibility Effects & Task Training:

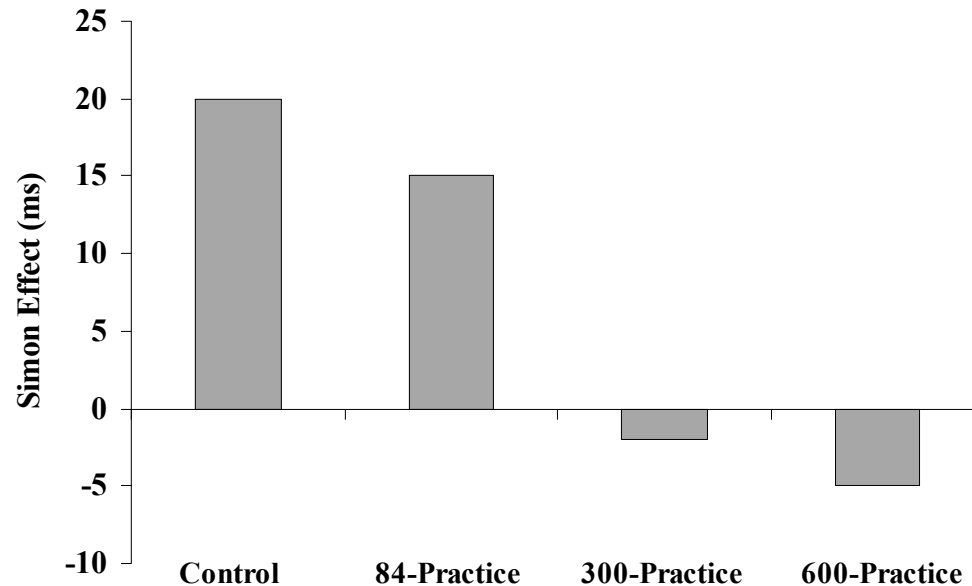
- Perfect transfer between location and arrow.
- Word stimuli did not produce significant transfer.



Compatibility Effects & Task Training:

Extended practice for word stimuli

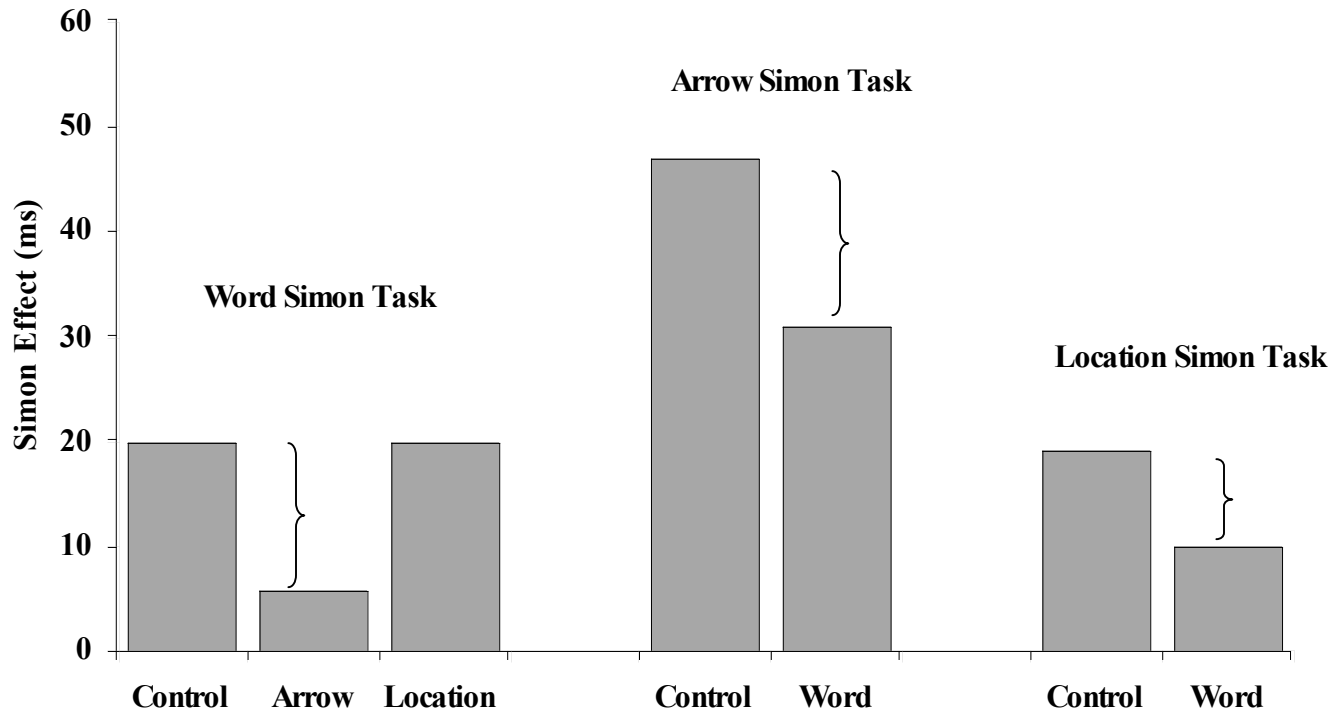
- As with auditory stimuli, word stimuli required extended practice for transfer to occur.



Compatibility Effects & Task Training:

Transfer across stimulus modes after extended practice

- Transfer between word and arrow was evident after extended practice.
- Transfer between word and location was not statistically significant.



Compatibility Effects & Task Training:

d) Response code

“RESPONSE” is a complex composite of multiple factors.

Three factors of “RESPONSE”

1. Response device



2. Response mode (action)



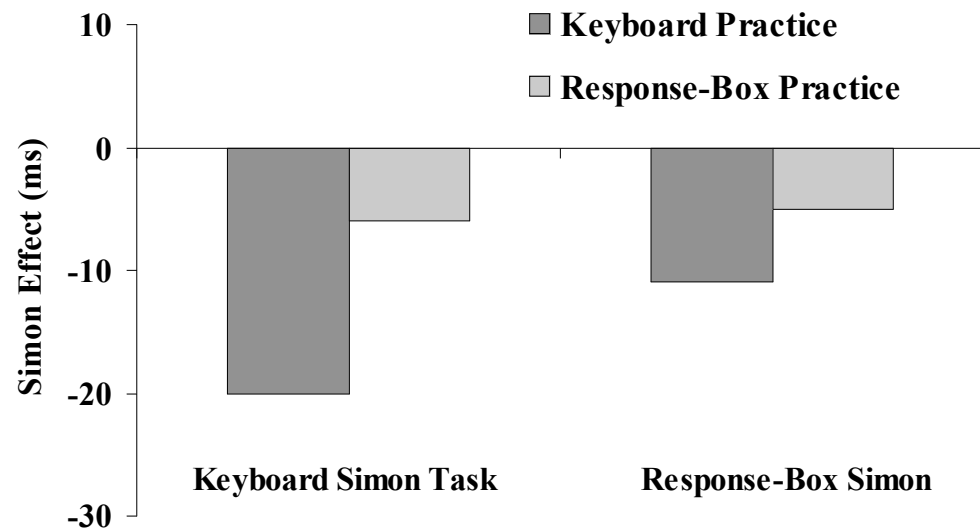
3. Action effect



Compatibility Effects & Task Training:

Response devices

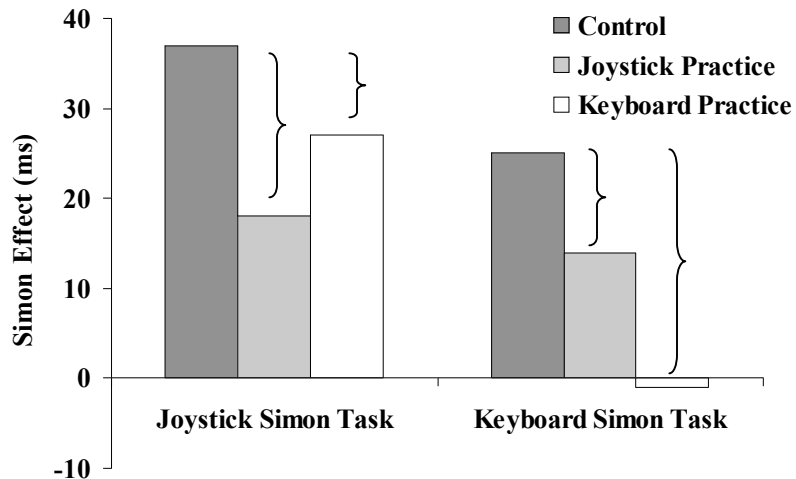
- Maintaining response mode (keypresses), there was nearly perfect transfer between response devices (keyboard – response box).



Compatibility Effects & Task Training:

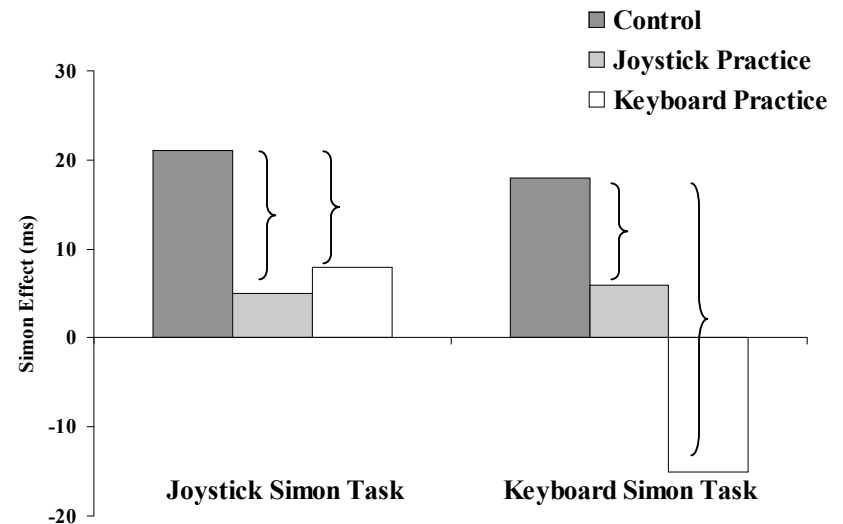
Response modes

- Transfer between different response modes was smaller than within the same mode.



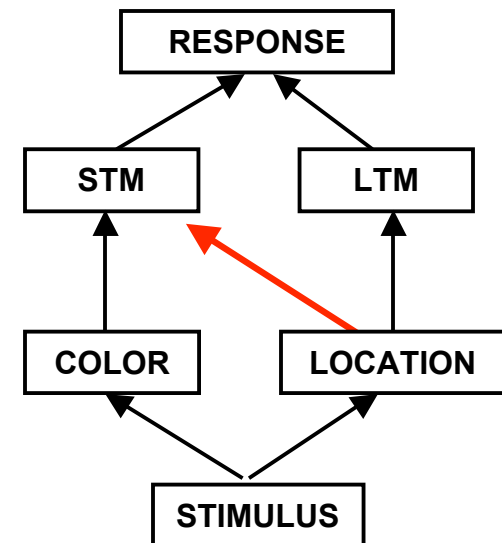
Action effect

- The Simon effect was generally smaller with action effect than without it.
- However, transfer was smaller for different response modes.



Compatibility Effects & Task Training:

- Transfer appeared to be specific to trained spatial dimension, sensory modality, stimulus code, and response mode.
- Specificity of transfer effect indicates that a newly acquired STM-link is specific to trained contexts.
- At the same time, extended practice often, but not always, generalizes trained skills to wider contexts.
- This generalization seems to indicate an acquisition of “rule-based” response selection.



Implications for Training & Interface Design:

Compatibility Principle

- One of the major factors affecting the speed and accuracy of response selection is the compatibility between stimulus and response.
- Compatibility is particularly important in human interfaces and display designs.
- It helps to increase the efficiency of operations and reduce human errors.

Implications for Training & Interface Design:

Training specificity principle

- Trained skills tend to be specific to the context of training (Healy et al., 2006); benefits of training are maximal when the training condition approximates the actual condition in which the acquired skills are required.
- Perceptual-motor skills benefit from relatively short practice, but such a skill tends to be sensitive to contextual factors: spatial dimension, sensory modality, stimulus code, and response mode.
- A trained task can be elaborated to a “rule-based” response-selection skill with extended practice, overcoming the contextual specificity of training.
- But it may be *expensive* in terms of training costs

Combat Identification Issues:

Why are the **compatibility** and **training specificity** principles important in CID?

- Obviously, CID depends heavily on advanced tracking technologies; **compatibility** issues in both task-relevant and task-irrelevant properties of display and interface are very basic in reducing human errors.
- Given the specificity of trained skills, **consistency** of operations, especially in the relationship between how information is presented and how it is acted on, with existing technologies should be a high priority when developing a new interface.

Both *compatibility* and *consistency* are key factors in development of new CID technologies.

End of Slides

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CID workshop

Additional slides

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Topics:

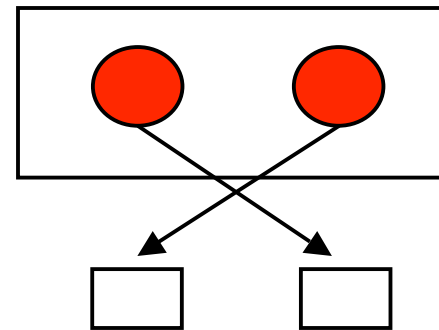
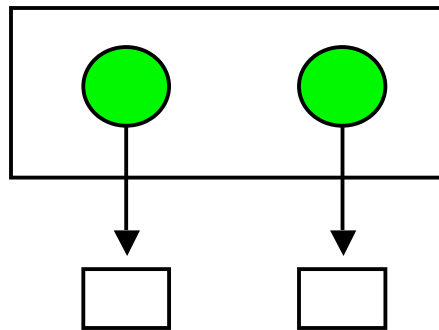
1. Compatibility effects with multiple tasks
2. Training & compatibility effects

1. Compatibility Effects with Multiple Tasks:

Mixed mappings

- With ***pure*** mappings, the compatible and incompatible mappings are separated into two blocks.
- With ***mixed*** mappings, the two mappings are intermixed within a single trial block

e.g., If a signal is green, press a key on the same side as the signal
If a signal is red, press a key on the opposite side to the signal

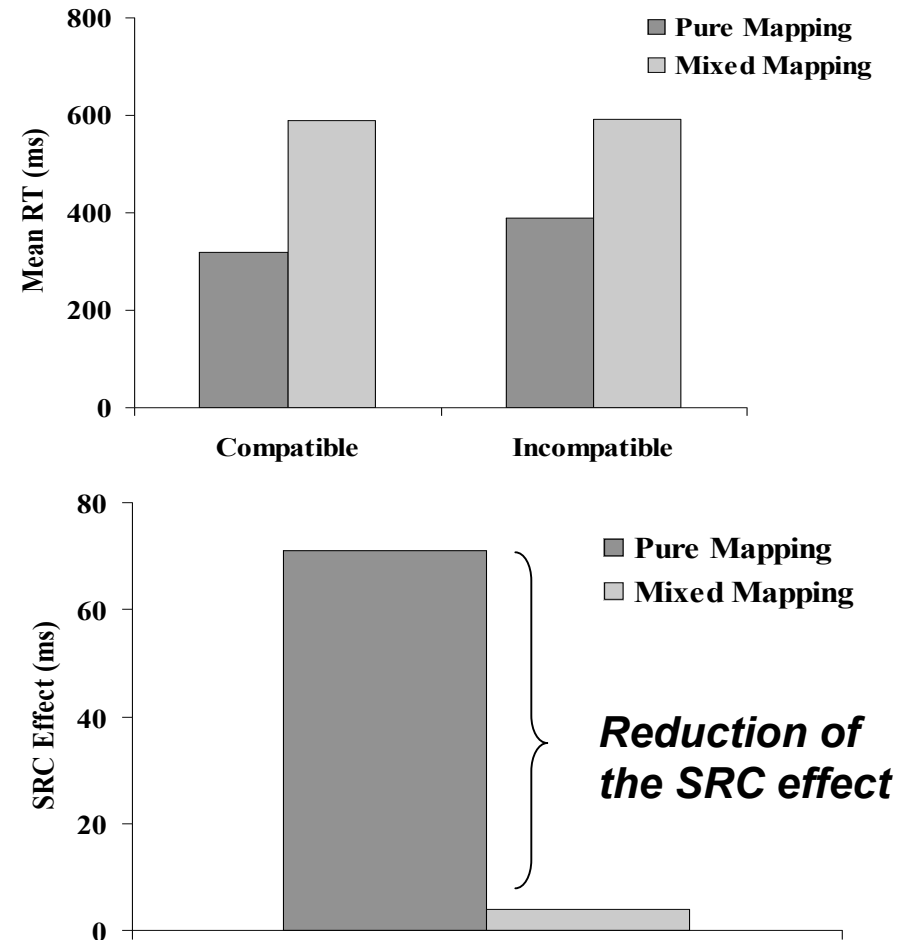


1. Compatibility Effects with Multiple Tasks:

Influences of mixing two mappings

(Vu & Proctor, 2004)

- Responses are generally slower and less accurate = *mixing cost*
- The advantage of compatible mapping is significantly reduced with mixed mappings



1. Compatibility Effects with Multiple Tasks:

- Reduction of the SRC effect is attributed to *suppression* of automatic activation of the corresponding response (De Jong, 1995)
- With two mappings being mixed, automatic activation of the corresponding response leads to an error when the incompatible response is required.
- Thus, the need for suppression comes from the need to prevent a high overall error rate.

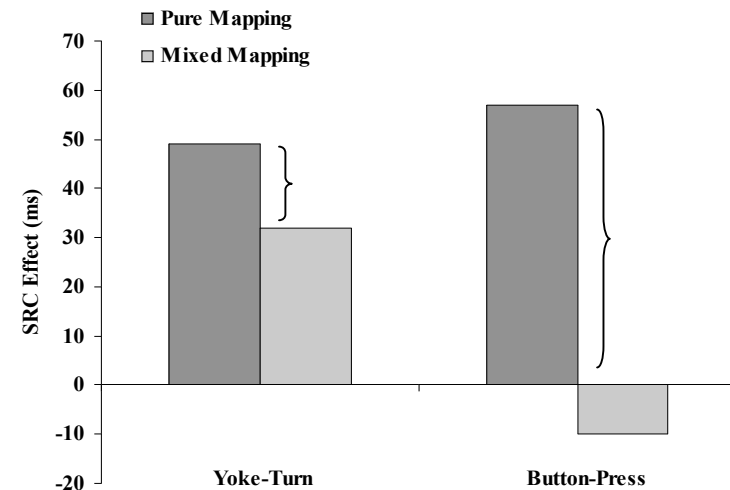
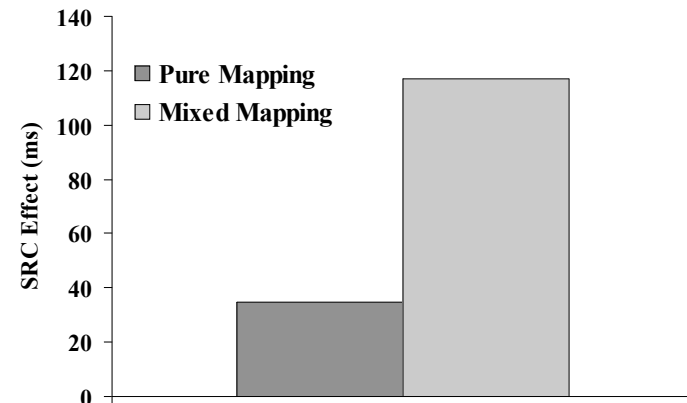
1. Compatibility Effects in Multiple Tasks:

- However, the SRC effect is not always reduced with mixed mappings.
- For instance, it 'increased' when stimuli were the words LEFT and RIGHT, and responses were button-presses.

(Vu & Proctor, 2004)

- Also, the amount of reduction differed for different response modes with the same stimuli.

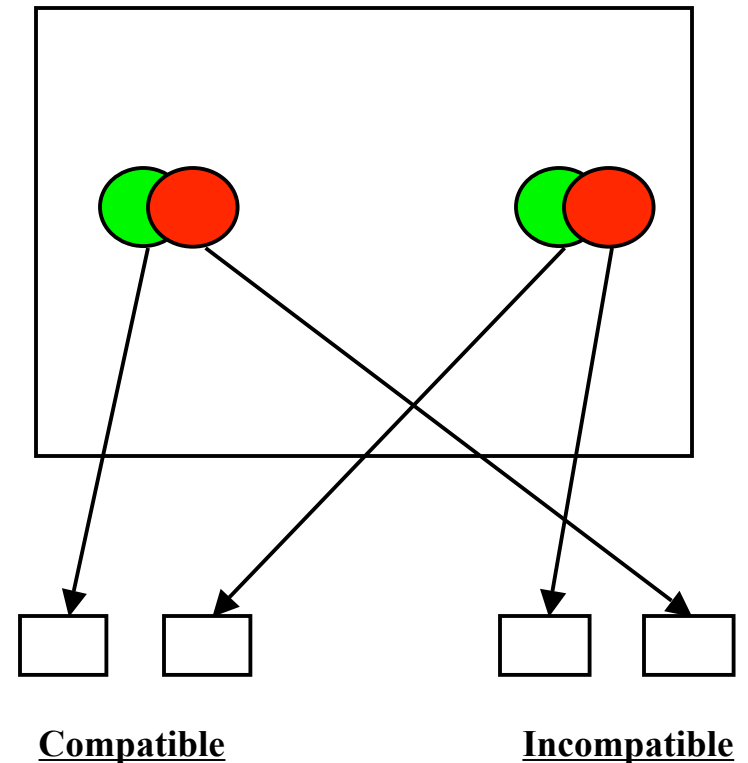
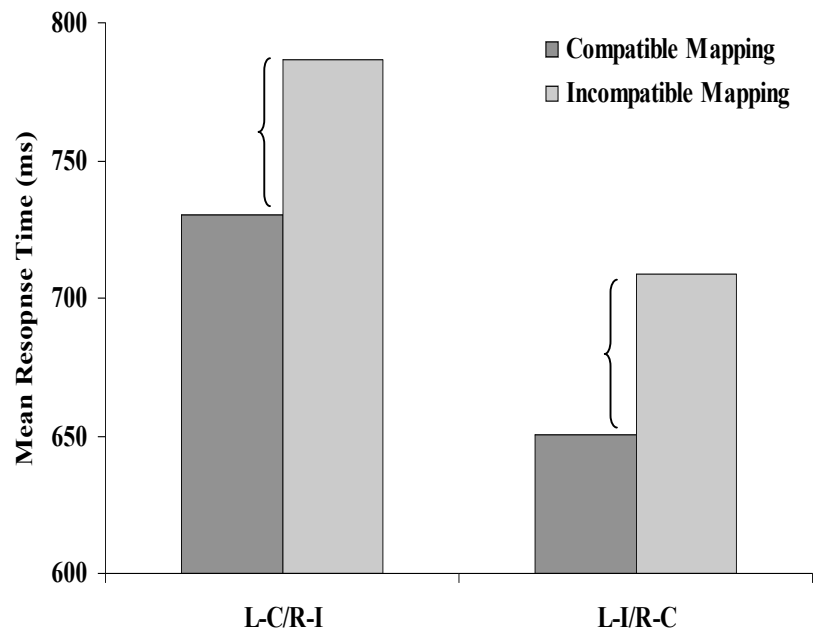
(Yamaguchi & Proctor, 2006)



1. Compatibility Effects in Multiple Tasks:

- Similarly, the SRC effect was not reduced when the compatible and incompatible mappings were assigned to different subsets of responses.

(Proctor & Vu, 2008)



1. Compatibility Effects in Multiple Tasks:

Reductions of the SRC effect is:

- ⊕ **Code-specific:** Automatic activation of response occurs when stimulus- and response-codes are highly compatible (*more discussion in the next section*).
- ⊕ **Response-specific:** Automatic activation of response depends on the complexity of action preparation.
- ⊕ **Dependent on response conflict:** Mixing costs and elimination of the benefit for compatible mapping occur mainly when the two tasks share responses. When two mappings are assigned to different subsets of responses, there is little conflict because the mapping to response sets is consistent, rather than variable.

Therefore,

“The SRC effect often emerges even in complex task conditions.”

Implications for Training & Interface Design:

Compatibility Principle

- One of the major factors affecting the speed and accuracy of response selection is the compatibility between stimulus and response.
- Compatibility is particularly important in human interfaces and display designs.
- It helps to increase the efficiency of operations and reduce human errors.
- However, the advantage of compatibility is *suppressed*, when operations involve incompatible display-control relationships.
- Also, suppression of the compatible mapping depends on stimulus- and response-codes, response complexity, and assignment of two mappings to subsets of responses.