



# Unimodal & Bimodal Numerosity Judgments

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## Introduction

- Research on people's ability to make numerosity judgment has revealed a discontinuity in judgments of small ( $\leq 4$ ) vs. large ( $> 4$ ) numbers of visual stimuli, consistent with people shifting from a strategy of subitizing (attention-free & errorless) to one of counting (attention-demanding & error-prone; e.g., Peterson & Simon, 2000).
- The majority of numerosity studies published to date have used visual stimuli. Very few studies have attempted to investigate people's ability to count stimuli presented to other sensory modalities, such as audition or touch.
- However, given recent interest in the use of tactile interfaces for humans operators in various applied settings (e.g., Ho, Tan, & Spence, in press; Van Veen & Van Erp, 2000), it is important to determine the limits of tactile perception in discriminating multiple stimuli presented over the body surface.



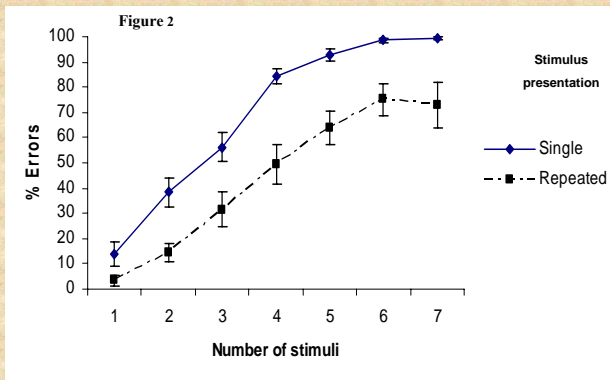
**EXPERIMENT 1:** Participants (N=10) attempted to count the number of vibrotactile stimuli (1-7) presented across their body (see Figure 1).

The vibrotactile stimuli were delivered by means of a custom-built 9-channel amplifier circuit that drove each tactor independently at 290 Hz.

Conditions of single (200 ms) vs. repeated (12 x 200 ms) presentation compared.

## Results

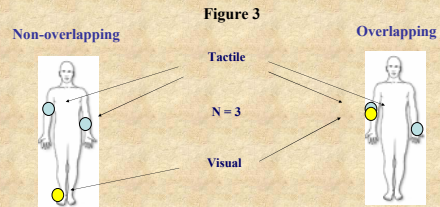
- No evidence for a discontinuity in performance was found, arguing against the presence of a subitizing effect for tactile numerosity judgments (see Figure 2).
- Performance better for repeated than for single presentation.



**EXPERIMENT 2:** Participants (N=14) counted the number of stimuli presented across their body regardless of the modality of presentation. We used 1-6 vibrotactile and 1-6 visual stimuli.

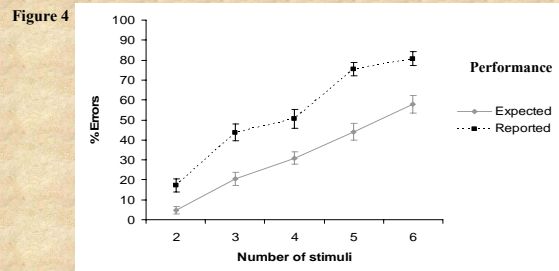
Tactile stimuli were presented as in Experiment 1. Visual stimuli presented via the mirror reflection of LEDs mounted directly above the factors (see Figure 1).

We compared bimodal and unimodal stimulus presentation. In bimodal trials, visual and tactile stimuli were equiprobably presented at overlapping, or non-overlapping positions (see Figure 3).



## Results

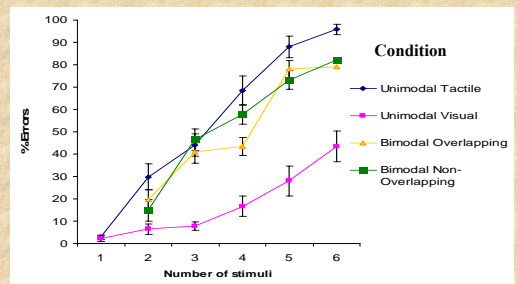
- The accuracy of bimodal numerosity judgments was not predicted by performance on the unimodal displays (see Figure 4).



- Worst performance reported in the unimodal tactile condition, best performance in the unimodal visual condition (see Figure 5).

- Performance in bimodal conditions worse than in unimodal conditions (despite the availability of redundant modality cues on bimodal trials).

Figure 5



- Participants' error slopes linearly related to the number of stimuli presented in the display.
- The number of errors in the bimodal conditions with overlapping vs. non-overlapping stimuli did not differ significantly.

## Discussion

- Subitizing does not appear to affect tactile perception.
- Our results highlight a severe limitation on the awareness of tactile stimuli presented to the body: People can only count (or are only accurately aware of) 2-3 stimuli on their body at anyone time, even under conditions of repeated presentation.
- Attentional/cognitive limitations appear to affect tactile numerosity judgments.
- The fact that bimodal numerosity judgments cannot be predicted on the basis of unimodal judgments may reflect crossmodal integration, the sharing of cognitive/attentional resources, and/or common spatial representations possibly accessed by both visual and tactile stimuli.
- Other attentional/cognitive limitations (such as change blindness) have also recently been shown to affect visuo-tactile perception over the body as well (see Gallace, Ho, & Spence, 2005, submitted).

## References

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