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Effects of cognitive load on selective and divided auditory spatial attention


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BACKGROUND

- Previous research found asymmetries in target detection and reaction time when targets were defined by phonetic vs. semantic features [1].
- Previous experiment conflated target definition (phonetic vs semantic) with number of unique words per auditory stream.
- This experiment: vary words-per-category and category identity in a spatial divided attention semantic judgment task (oddball paradigm).

QUESTIONS

- Does number of words in the category influence performance on the category judgment task?
- Is there a performance benefit when the two attended streams comprise the same category?

TABLE 1: word categories and target words.

SIX-WORD CATEGORIES

FOOD	FURNITURE	COLORS	WEATHER
bread	bed	blue	hail
stew	desk	gray	rain
meat	chair	green	frost
cake	lamp	pink	wind
fruit	stool	red	storm
rice	couch	tan	cloud

THREE-WORD CATEGORIES

FRUITS	BIRDS	FISH	DRINKS
lime	hawk	eel	wine
fig	duck	bass	juice
grape	goose	cod	tea

TARGET WORDS

arm	chin	glove	leg	rat	stem
bark	cow	goat	mouse	scarf	stick
bear	dog	hat	mouth	sheep	suit
belt	dress	horse	nose	shirt	thigh
branch	foot	knee	pants	shoe	thorn
cat	fox	leaf	pig	skirt	wrist
purse	snake				

HYPOTHESES

- Tasks with fewer words per category will show faster reaction times, but also more false alarms.
- Performance will be higher when the two attended streams comprise words from a single category vs. two different categories.

STIMULI

- New recordings of monosyllabic words from 8 semantic categories (3 or 6 words per category) plus 38 control words (see Table 1).
- Categories were similar in:

lexical frequency	$F(7,28)=2.067$ $p=0.08$
neighborhood density	$F(7,28)=0.318$ $p=0.94$
mean uniphone frequency	$F(7,28)=1.422$ $p=0.24$
mean biphone frequency	$F(7,28)=1.592$ $p=0.18$

- Words monotonized to talker's mean f_0 (107 Hz) [2].
- Words RMS normalized and concatenated into 4 temporally interleaved 12-word streams per trial. Across-stream ISI: 250 ms, within-stream ISI: 750–1750 ms (see Figure 1).
- Streams spatialized at ±15° and ±60° azimuth by convolving with anechoic HRTFs from [3].

PROCEDURE

- Word categorization test prior to main task to ensure consistent categorization across subjects.
- 5-step training to ensure mastery of all aspects of the task (attend one stream, attend multiple streams, ignore streams, etc).
- On each trial, all 4 categories shown in grey text on black screen, spatially arranged to mimic angles of the audio streams. 1 stream (selective attention control) or 2 streams (divided attention) colored green indicating "to be attended." Stimulus began 2500 ms later. Listeners responded by button press to targets in the to-be-attended stream(s).
- Trials blocked by words-per-category (3 or 6); half the participants did small-category blocks first, half did large-category blocks first.
- 120 trials (6 blocks of 20), 3-4 oddballs per trial (2-3 attended stream "targets," 0-2 ignored stream "foils"). 48 selective attention (control) and 72 divided attention trials. Half of divided attention trials had same-category attended streams; half had spatially adjacent attended streams. All trial parameters (words/category, spatial configuration, and attended categories same/different) were counterbalanced.

ANALYSIS

- Repeated measures ANOVA with 3 within-subjects factors [4,5]:

```
dprime ~ WordsPerCatg * SpatCfg * AttnCatgID +
         Error(WordsPerCatg * SpatCfg * AttnCatgID)
```

	F(1,9)	p-value	Effect size (η^2_G)
WordsPerCatg	**28.017**	**0.0005 *****	**0.127029**
SpatCfg	**22.933**	**0.0010 ****	**0.088450**
AttnCatgID	3.041	0.1152	0.017666
WrdPrCat:SptCfg	0.002	0.9629	0.000006
WrdPrCat:AtnCatID	2.873	0.1243	0.014066
AtnCatID:SptCfg	**39.163**	**0.0001 *****	**0.053747**
WdPrCt:AtnCtID:SpCfg	0.470	0.5101	0.002233

RESULTS

- Main effects of words per category and spatial configuration (Figure 2, blue and yellow bars)
- Interaction between spatial configuration and attended category identity (Figure 2, orange bars)
- Significant difference in reaction times for words per category, driven mostly by spatially separated condition (Figure 3, blue and green bars)
- High false alarms in separated + same condition (Figure 4, orange bars)

DISCUSSION

- Main effect of words per category suggests cognitive load imposed by acoustic complexity of the scene; follow-up experiment will assess with pupillometry
- Adjacent streams + same category = big advantage; may be explained by broadened attentional spotlight
- Faster reaction times and more false alarms with 3-word categories than with 6-word categories; suggests possible shift in listener strategy to attend to word sound rather than meaning

FIGURE 1. Sample trial structure. LEFT: screenshot of visual prime. CENTER: schematic of spatial mapping of categories. RIGHT: Trial time course; to-be-attended streams have white backgrounds, ignored streams have grey backgrounds; small rectangles are actual word durations; targets are green, and foils are red.

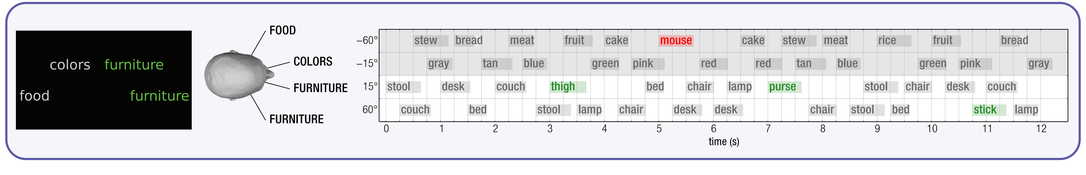


FIGURE 2: d-prime scores for main effects (top) and two-way interactions (bottom). Brackets show *p*-values from post-hoc planned comparison *t*-tests (Holm-Bonferroni corrected).

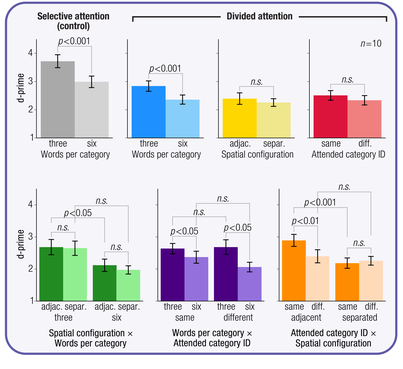


FIGURE 3: Reaction times for main effects (top) and two-way interactions (bottom). Brackets show *p*-values from post-hoc planned comparison *t*-tests (Holm-Bonferroni corrected).

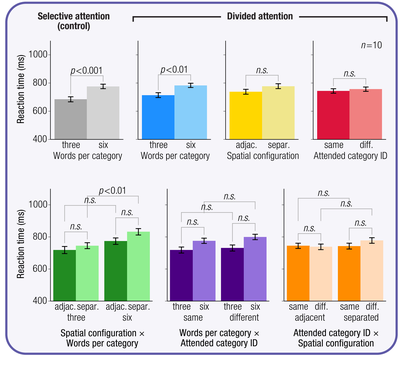
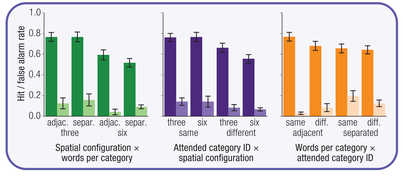


FIGURE 4: Hit and false alarm rates for the two-way interactions.



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