SIGNAL DETECTION, AGING, AND CONTINGENCY ASSESSMENT

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Abstract

The number of articles concerned with contingency assessment has increased steadily since the pioneering research by Herbert Jenkins and colleagues in 1965. Around the same time Fergus Craik argued that aging effects on performance should be analyzed within a psychophysical framework. Surprisingly, there have been few reports about the effect of age on contingency assessment, and none of these have incorporated a psychophysical approach. We will present research demonstrating the utility of applying psychophysical methodology to understanding differences in contingency assessment seen in older participants (seniors) compared with university students.

Forty years ago Craik (1969) advocated the application of Signal Detection Theory (SDT) to the study of the effect of aging on cognitive functioning. A few years earlier, Jenkins and Ward (1965) and Ward and Jenkins (1965) published two, now-classic papers on contingency assessment. In studies of contingency assessment a participant is asked to judge the relationship between events, a cue and an outcome. Although there are various forms of the task, a discrete trial format with a single cue and a single outcome often is used. On each trial the cue either is presented (C) or is not presented (~C), and then the outcome either does occur (O) or does not occur (~O). A commonly used measure of the contingency between the cue and the outcome is ΔP (Allan 1980):

$$\Delta P = P(O \mid C) - P(O \mid {\sim} C)$$

As documented by Siegel et al. (2009), contingency assessment research has grown exponentially since the pioneering research of Jenkins and colleagues. Recently, we have made the case that that psychophysics in general, and signal detection theory (SDT) in particular, can profitably be applied to understanding contingency assessment (Allan et al., 2008; Siegel et al., 2009). Given the increasing interest in the effects of aging on cognitive functioning, it is surprising that there are few papers directed at aging and contingency assessment. Most contingency assessment studies have used college students, and few have directly compared the performance of students with the performance of older participants. The reports that do exist suggest that older participants sometimes differ from the younger cohort (e.g., Mutter & Williams, 2004; Parr & Mercier, 1998). However, none of the studies have used a SDT framework. Thus, when differences are reported, we do not know the locus of such age related changes: Are they due to changes in sensitivity to the contingency, or changes in the response criterion?

The present experiments were designed to further our understanding of differences in contingency assessment displayed by younger and older individuals. We have developed a new version of the contingency task, the streamed-trial procedure (Crump et al., 2007), which is especially suited to examining contingency assessment using psychophysical procedures. Allan et al. (2008) and Siegel et al. (2009) used this streamed-trial procedure, in conjunction with the method of constant stimuli, to generate psychometric functions using participants who were undergraduate and graduate students at McMaster University. In the experiments reported in the present manuscript, the participants are members of the Hamilton community, aged 66 and older ("seniors"), and we compare their performance with that reported previously for the younger participants.

Experiment 1: The Psychometric Function

In Experiment 1 we use the method of constant stimuli to explore contingency sensitivity in older participants, and we compare their performance with the younger participants reported in Experiment 1C in Allan et al. (2008).

Method

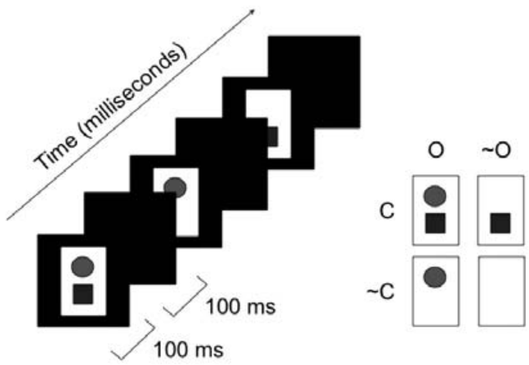

Fig 1. A streamed-trial in Experiment 1.

The 17 participants ranged in age from 66 to 82 (mean = 73.8). The streamed trial is depicted schematically in Fig 1. The cue was a blue square and the outcome was a red circle. The four possible cue-outcome combinations are also shown in Fig 1. A cue-outcome pair was presented for 100 ms, and cue-outcome frames were separated by a black 100-ms frame. A stream of 60 cue-outcome presentations, with a total duration of approximately 12 sec, defined a value of ΔP. At the end of each streamed-trial, the participant was required to make a binary decision about the strength of the contingency between the square and the circle - "weak" (a R_W response) or "strong" (a R_S response). There were 11 values of ΔP ranging from 0.0 to 1.0 in increments of 0.1. Each of the 11 ΔP values was presented four times in a randomized order during each block of 44 streamed-trials. A session consisted of five blocks, resulting in 20 presentations of each of the 11 ΔP values.

Results and Discussion

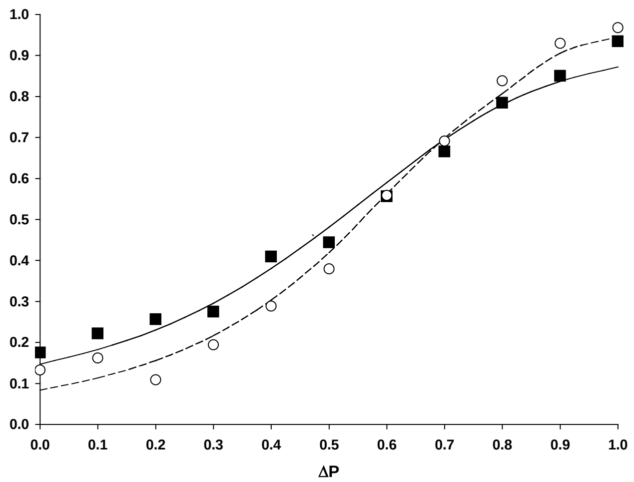

Fig 2. Psychometric function for seniors in Experiment 1 (filled squares and filled line) and for younger participants in Allan et al. (2008, Experiment 1C) (open circles and dashed line).

One participant was strongly biased to responding strong to all ΔP values and those data were excluded. Fig 2 displays $P(R_S)$ as a function of ΔP averaged over the 16 participants. The cumulative normal psychometric function was fit to the data of each of the 16 participants using ProFit (http://www.quansoft.com/). The function shown in Fig 2 is the mean of the 16 individual fitted functions. For comparison, Fig 2 also shows the data from the undergrads in Experiment 1C in Allan et al. (2008). The slope of the function for the seniors is less steep than the younger slope.

The psychometric function allows the extraction of two parameters from the data. One parameter, σ (the reciprocal of the slope), provides a measure of the participant's sensitivity to the contingency. The other parameter, the point of subjective equality (PSE), is the value of ΔP at which $P(R_S) = .5$. The PSE provides a measure of the participant's preference or bias for making a particular response. The mean values of these parameters are available in Table 1. Also shown are the values for the 17 undergrads in Experiment 1C in Allan et al. (2008). Table 1 indicates that the seniors are less sensitive (larger values of σ) than the undergrads. For both groups there is little bias with the PSE close to .50. A Mann-Whitney U test on the σ values confirms that the two age groups differ with regards to sensitivity, U = 80.5, $p < .05$. A Mann-Whitney U test on the PSE values confirms that the two groups do not differ with regards to bias, U = 120.5, $p > .05$.

Table 1. σ and PSE values in Experiment 1 and in Experiment 1C in Allan et al. (2008).

	Seniors	Undergrads
σ	.55	.33
PSE	.50	.51

Experiment 2: The Psychometric Function with Extended Practice

In Experiment 2, we investigate whether the age difference in sensitivity observed in Experiment 1 would be attenuated with practice. Rather than experiencing only one session, each participant completed 10 sessions. Except for the age of the participants, this experiment is identical to Experiment 1A in Allan et al. (2008).

Method

The seven participants ranged in age from 66 to 74 (mean = 71.1). The procedure was identical to Experiment 1 except that each participant completed 10 sessions.

Results and Discussion

Psychometric functions were fit to each participant's data averaged over the 10 sessions. The values of σ and PSE are available in Table 2 for each participant. Also given is R^2 – the proportion of the variance in the observed values of

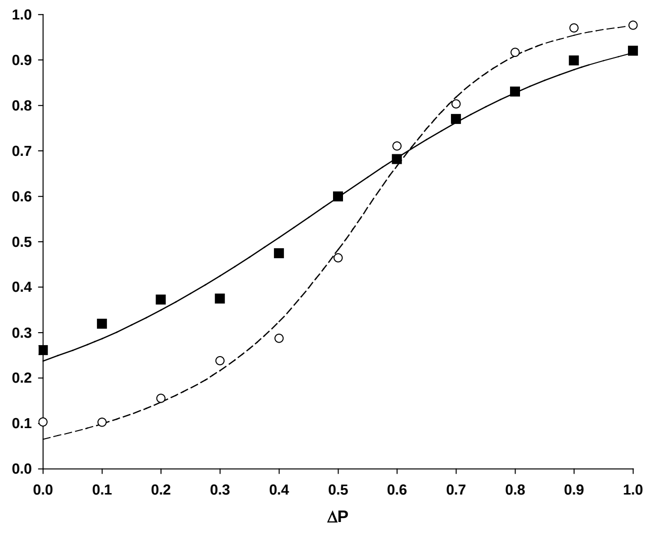

Fig 3. Psychometric function for seniors in Experiment 2 (filled squares and filled line) and for younger participants in Allan et al. (2008, Experiment 1A) (open circles and dashed line).

Table 2. σ, PSE, and R^2 values in Experiment 2 and in Experiment 1A in Allan et al. (2008)

		σ	PSE	R^2
Seniors	JM	.09	.84	.864
	GW	.32	.49	.984
	JeB	1.41	-.83	.905
	NW	.35	.43	.958
	JuB	.48	.41	.977
	ID	.30	.50	.991
	RD	.61	.35	.960
Grads	AC	.13	.56	.996
	MC	.18	.55	.996
	CT	.30	.43	.991
	JB	.41	.37	.969

$P(R_S)$ accounted for by the fitted function. For comparison, Table 2 shows the parameter values for the four younger participants (graduate students) in Experiment 1A in Allan et al. (2008). The fit for participant JM in the present experiment is poor, and her psychometric function clearly differs from the normal ogive. Omitting participant JM, three of the younger participants are more sensitive (smaller values of σ) than each of the six older participants. A randomization test on the 10 values of σ indicates that the two age groups differ in sensitivity ($p < .05$). A similar test on the 10 PSE values indicates that the two age groups do not differ in PSE ($p > .05$).

Fig 3 displays $P(R_S)$ as a function of ΔP averaged over the participants in each age group. The functions shown in Fig 3 are the mean of the individual fitted functions. As in Experiment 1, the senior slope is less steep than the younger slope. The results of Experiment 2 indicate that after 10 sessions older participants are still less sensitive than the younger participants.

Experiment 3: Cue Interaction

The results of Experiments 1 and 2 showed that contingency sensitivity decreases with age, even after extended practice on the task. Although the differences between the two age groups were significant, the ability of the seniors to discriminate among the contingency values was clearly above chance. In Experiment 3, we use a more complex task, one-phase blocking, which requires the monitoring of two contingency values. Except for the age of the participants, Experiment 3 is identical to that reported in Siegel et al. (2009) with younger participants.

Method

The five participants ranged in age from 68 to 72 (mean = 70.4).

In one-phase blocking, two cues, a target cue (C_T) and a companion (C_C), are paired with a common outcome. The two cues result in four possible cue combinations: both cues may be present ($C_T C_C$), both cues may be absent ($\sim C_T \sim C_C$), the target may be present and the companion absent ($C_T \sim C_C$), or the target may be absent and the companion present ($\sim C_T C_C$). For each cue combination, the outcome either occurs (O) or does not occur (~O), resulting in eight cue-outcome combinations. Fig 4 shows the streamed-trial procedure, as adapted by Hannah et al. (2009), for the one-phase blocking paradigm. Cues are blue squares and blue triangles, and the outcome is a red circle. The eight possible cue-outcome combinations are also depicted in Fig 4. A cue-outcome pair was presented for 100 ms, and cue-outcome frames were separated by a black 100-ms frame. The location of each shape, when it was present, was constant across all frames: the red circle was centered above the blue shapes, the blue square was on the left, and the blue triangle was on the right.

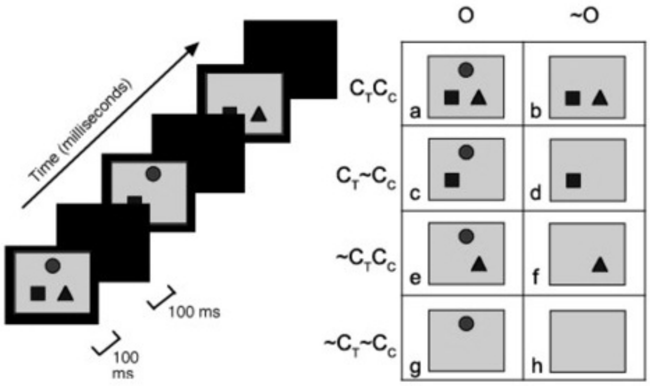

Fig 4. A streamed-trial in Experiment 3.

The participants were told that their task was to categorize the strength of the relationship between a blue shape (cue) and a red circle (outcome) as weak or strong. Either square or triangle could function as C_T or as C_C in any given stream. Streams were composed so that one blue shape, C_T, had (on different streams) a contingency of 0.2, 0.4, 0.6, or 0.8 with the circle, while its C_C had a contingency of 0.0 or 1.0 with the circle. The two values of C_C contingency (0.0, and 1.0) were crossed with the four values of C_T contingency (0.2, 0.4, 0.6, 0.8), resulting in eight 4 x 2 contingency matrices (available in Siegel et al., 2009). Each streamed trial consisted of a sequential display of randomly ordered presentations of the eight cue-outcome combinations defined by one of the contingency matrices.

An experimental session consisted of five blocks of 48 streamed-trials. Each of the eight contingency matrices occurred six times in a block in a randomly determined order. The duration of a streamed trial was approximately 8 seconds. At the end of each stream, the participant was required to make a binary response (R_W or R_S) about the relationship between *one* of the cues and the outcome. The participant was informed which cue-outcome relation to judge by a small picture appearing on the screen at the end of the stream showing one of the two cues and the outcome. For each of the eight contingency matrices, C_T was probed at the end of half the streams and C_C was probed at the end of the remaining streams. Each participant completed 15 sessions.

Results and Discussion

Fig 5 shows $P(R_S)$ on C_T-probed streams, averaged over the five participants, plotted as a function of C_T ΔP for each of the two C_C contingencies (filled symbols). For comparison, the data from the younger participants in Siegel et al. (2009) are reproduced (open symbols). We see a dramatic difference between the two age groups. The senior slopes are essentially flat indicating little discrminability among C_T values (ranging from .2 to .8) that were well

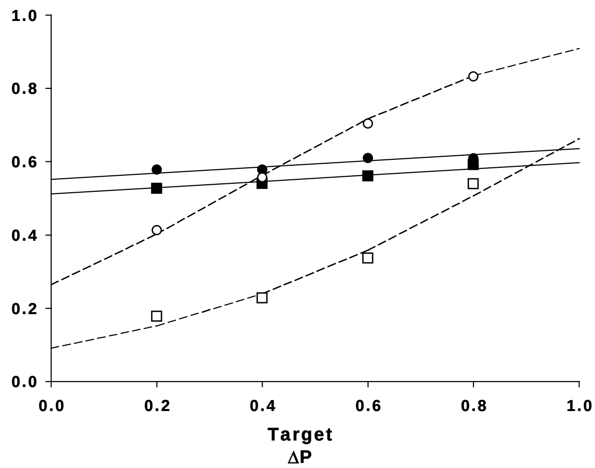

Fig 5. C_T psychometric functions for seniors in Experiment 3 (filled symbols and lines) and for younger participants in Siegel et al. (2009) (empty symbols and dashed lines). Circles denote C_C $\Delta P = 0$, squares denote C_C $\Delta P = 1.0$

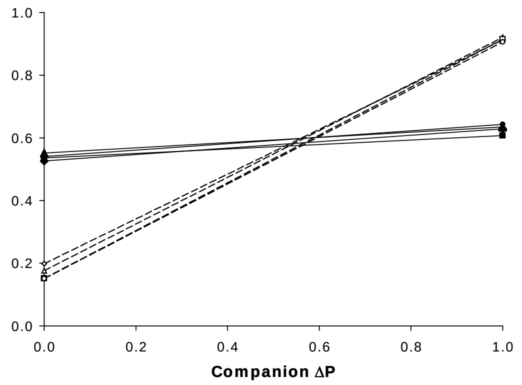

Fig 6. C_C psychometric functions in for seniors in Experiment 3 (filled symbols and lines) and for younger participants in Siegel et al. (2009) (empty symbols and dashed lines)

discriminated by seniors in the single-cue task in Experiments 1 and 2. The functions shown in Fig 5 are the mean of the individual fitted functions. For both age groups, the PSE is larger when C_C $\Delta P = 1$ (squares) then when C_C $\Delta P = 0$ (circles). This is the cue-interaction effect – responses to the target contingency depend on the value of the companion contingency. However, the size of the cue interaction effect for seniors is trivial.

Fig 6 shows $P(R_S)$ on C_C-probed streams, averaged over the five participants, plotted as a function of C_C ΔP for each of the four C_T contingencies (filled symbols). For comparison, the data from the younger participants in Siegel et al. (2009) are reproduced (open symbols). For both age groups, the psychometric functions are similar for the four C_T ΔP values. C_T contingency had little effect on either the slope or the PSE. However, the two age groups differ with regard to the slopes of the four functions. For the seniors, there is little discrimination between ΔP = 0.0 and ΔP = 1.0, two values that were well discriminated by seniors in the single-cue task in Experiments 1 and 2.

Concluding Comments

Our data clearly indicate that seniors are less sensitive to ΔP differences than are younger participants. While this age effect is present in the single-cue task in Experiments 1 and 2, it is much larger when the task requires the participant to monitor two independent contingencies as in the one-phase blocking task in Experiment 3. In Experiment 3, the seniors were unable to discriminate ΔP values that they could discriminate in Experiments 1 and 2. This pattern of results is suggestive of an age-related decrement in the ability to segregate competing sources of information in the display.

Acknowledgements

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