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Stability of parameters in repeated TVA measures
Whole Report versus Change Detection

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ABSTRACT
Several recent studies have explored the limitations of human visual short-term memory or VSTM (e.g. Luck & Vogel, 1997; Wheeler & Treisman, 2002; Alvarez & Cavanagh, 2004). Usually researchers agree that VSTM is limited to a capacity of about 3 to 4 objects at any given moment (Cowan, 2001).

INTRODUCTION
The visual short-term memory (VSTM) store has been found to have a very limited capacity (K), compared to the human long-term memory store. Usually researchers have reported that VSTM is limited to around 3 to 4 objects (Sperling, 1960; Bundesen, 1990). Luck and Vogel (1997) have argued that VSTM capacity is limited only with respect to the total number of objects in the visual field independent of the number of individual features represented within the objects. Other researchers have tried to argue for an information based account where it is the sum of the complexity rather than the individual objects per se that is the limiting factor in VSTM (e.g. Alvarez & Cavanagh, 2004). A background assumption in the studies measuring K must be that K is a stable parameter over time; the idea that attentional parameters are stable within subjects is a fairly common assumption (Wundt, 1890; Cowan, 2001). This assumption however has not been empirically tested.

The aim of the present study is to investigate the stability of attentional estimates of capacity (K) and general speed of processing (C), using the Theory of Visual Attention (TVA) model as a framework (Kyllingsbæk, 2006). Furthermore two paradigms were deployed; the widely used change detection paradigm (Phillips, 1974) and the whole report paradigm (Sperling, 1960).

EXPERIMENT
In the Experiment, it was investigated how subjects perform in a repeated measure design. Two experimental paradigms were used; whole report (WR) and change detection (CD). Optimized versions of both WR and CD paradigms were used. The WR paradigm used was almost identical to the paradigm used in the Betula study (Vangkilde, Kyllingsbæk, Habelost, Bundesen, Marklund, & Nielsen, 2009). The CD paradigm was modelled over the WR paradigm and varied only when subjects had to make a response, where a probe screen would be presented instead of the standard whole report screen (figure 1). Furthermore, the CD paradigm which is usually performed as a two alternative forced-choice task was optimized in regard to the recommendations of Kyllingsbæk & Bundesen (2009). Here subjects are instructed to be fairly certain of their response and if subjects are uncertain they are instructed to press a third button indicating “no answer”.

In both paradigms the stimulus used consisted of 20 letters [A, B, D, E, F, G, H, J, K, L, M, N, O, P, R, S, T, V, X, & Z] and six different exposure durations was used from 10 - 200ms [10, 20, 50, 80, 140, & 200]. The WR paradigm was comprised of 3 blocks of 48 trials and the CD paradigm, which is more noisy, was comprised of either 3 [Subjects 5, 7, & 8] or 6 [Subjects 1, 2, & 4] blocks of 144 trials. The order in which subjects did the CD and WR was varied between each session, odd-number subjects would do CD- WR/WR-CD/WR-CD/WR/CD-WR/CD-WR and even-number subjects would perform the two paradigms in the reverse order WR-CD/WR/CD-WR/WR-CD-WR/CD-WR/CD-WR.

Capacity of short-term memory is measured in a range of studies often using the change detection paradigm (CD). However, the whole report paradigm (WR) may be a more reliable paradigm (Casas, Lehmann, Veldsman, & Mitchell, 2009). Moreover, each individual WR trial yield more information compared to a CD trial.

Subjects
Six subjects where tested in seven separate sessions. Each of the sessions was placed at the same time of the day ±1 hour and were as evenly distributed as possible. Participants were volunteering students and lab members from our department.

Results
Data was modelled within the TVA framework and obtained estimates for K and C parameters over the seven trials. K estimates are usually more stable than estimates for C and with the limited number of observations per data point we were aware of potential problems in estimating C.

Repeated measure of capacity (K)
Investigating the results obtained from the repeated measures yielded fairly stable C estimates within the WR design, whereas the variance was too high in the CD condition. Moreover, it seems that there may be an effect of training in subjects 1 and 4 (see figure 2 above), both of these subjects where naive and had never previously participated in experiments - the rest of the subjects where naive to the task but have had previous experience with other experiments.

Repeated measure of the general processing speed (C)
The C parameter was also fitted to the model; the WR data fitted well, however, the CD data showed some difficulties in the fitting process (table 1), therefore only the whole report data are depicted in a graph below (figure 3).

CONCLUSION
Data from six subjects was presented in a repeated measure design with seven individual test sessions. Even with a very low number of trials (144 versus 432/864) the whole report design yield fairly stable K estimates compared to change detection, suggesting that a change detection design should only be used when a whole report is not possible (i.e. when subjects do not have category labels for the objects presented). C estimates, however, seem to be more prone to variation - the model can fit the data whole report data but the estimates vary between the individual sessions even when we try to fixate external parameters such as the times of testing.

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