TECHNICAL COMMENTARY

Time perception

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Introduction

Time perception involves the capacity to accurately process temporal information that is embedded in relevant events. The ability to perceive, remember, and organise behaviour in periods ranging from seconds to minutes mediates functions, from basic motor coordination to decision making. As time intervals make different demands on other cognitive processes, it is difficult to disentangle deficits in temporal perception from deficits in attention and memory.

There are several types of time perception. Explicit timing involves a deliberate estimate of a discrete duration of time, while implicit timing is an automatic process that is engaged whenever sensorimotor information is temporally structured. Automatic timing involves no attentional or cognitive modulation and is primarily involved in timing intervals in the subsecond range. Cognitively controlled timing is primarily based on higher level cognitive processes such as attention and memory that are recruited for longer periods. Accuracy indexes the ability to determine a particular value and precision refers to variability in judgements of that value. Perceptual timing involves estimates of duration in the form of perceptual discrimination, while motor timing involves estimates of duration in the form of motor response.

Method

We have included only systematic reviews (systematic literature search, detailed methodology with inclusion/exclusion criteria) published in full text, in English, from the year 2000 that report results separately for people with a diagnosis of schizophrenia, schizoaffective disorder, schizophreniform disorder or first episode schizophrenia. Reviews were identified by searching the databases MEDLINE, EMBASE, CINAHL, Current Contents, PsycINFO and the Cochrane library. Hand searching reference lists of identified reviews was also conducted. When multiple copies of reviews were found, only the most recent version was included. Reviews with pooled data are prioritised for inclusion.

Review reporting assessment was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist that describes a preferred way to present a meta-analysis[1]. Reviews with less than 50% of items have been excluded from the library. The PRISMA flow diagram is a suggested way of providing information about studies included and excluded with reasons for exclusion. Where no flow diagram has been presented by individual reviews, but identified studies have been described in the text, reviews have been checked for this item. Note that early reviews may have been guided by less stringent reporting checklists than the PRISMA, and that some reviews may have been limited by journal guidelines.

Evidence was graded using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group approach where high quality evidence such as that gained from randomised controlled trials (RCTs) may be downgraded to moderate or low if review and study quality is limited, if there is inconsistency in results, indirect comparisons, imprecise or sparse data and high probability of reporting bias. It may also be downgraded if risks associated with the intervention or other matter under review are high. Conversely, low quality evidence such as that gained from observational studies may be upgraded if effect sizes are large or if there is a dose dependent response. We have also taken into account sample size and whether results are consistent, precise and direct with low associated risks (see end of table for an explanation of these terms)[2]. The resulting table represents an objective summary of the available evidence, although the conclusions are solely the opinion

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of staff of NeuRA (Neuroscience Research Australia).

Results

We found four systematic reviews that met our inclusion criteria[3-6].

- Moderate to high quality evidence suggests a medium-sized effect of poorer explicit timing in people with schizophrenia than in controls, with no significant differences in the effect size according to type of timing task (automatic vs. controlled) or method of timing task (motor vs. perceptual).
- Moderate quality evidence finds a medium-sized association between poorer time perception and more severe positive symptoms.
- Moderate to high quality evidence finds similar, large effects of impaired temporal binding in people with schizophrenia and people with autism spectrum disorders.
- Moderate to low quality evidence finds large effects of poorer precision of time perception and poorer precision of temporal processing in people with schizophrenia compared to controls, with no differences in accuracy apart from in the medium temporal range (10 seconds to 10 minutes).

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Ciullo V, Spalletta G, Caltagirone C, Jorge RE, Piras F

Explicit Time Deficit in Schizophrenia: Systematic Review and Meta-Analysis Indicate It Is Primary and Not Domain Specific

Schizophrenia Bulletin 2016; 42(2): 505-18

View review abstract online

Comparison	**Time perception in people with schizophrenia vs. controls.**
Summary of evidence	**Moderate to high quality evidence (large sample, inconsistent, precise, direct) suggests a medium-sized effect of poorer explicit timing in people with schizophrenia than controls, with no significant differences in the effect according to type of timing (automatic vs. controlled) and method of timing task (motor vs. perceptual).**

Time perception

A significant, medium-sized effect of poorer explicit timing in people with schizophrenia than controls;

24 studies, N = 1,555, d = -0.64, 95%CI -0.82, to -0.45, $p < 0.001$, $I^2 = 67\%$, $p < 0.001$

Subgroup analysis of timing type revealed a non-significant, but larger effect size in the automatic timing subgroup than in the cognitively controlled subgroup (d = -0.75 vs. -0.47), and both effect sizes were statistically significant ($p < 0.001$).

Subgroup analysis of timing method revealed a non-significant, larger effect size in the perceptual timing subgroup than in the motor timing subgroup (d = -0.64 vs. -0.55), and both effect sizes were statistically significant ($p < 0.001$).

Authors report no evidence of publication bias.

Consistency‡	Inconsistent
Precision§	Precise
Directness‖	Direct

Thoenes S, Oberfeld D

Meta-analysis of time perception and temporal processing in

schizophrenia: Differential effects on precision and accuracy **Clinical Psychology Review 2017; 54: 44-64.** View review abstract online	
Comparison	**Accuracy and precision on time perception tasks in people with schizophrenia vs. controls.**
Summary of evidence	**Moderate to low quality evidence (unclear sample sizes, some inconsistency, imprecise, direct) finds large effects of poorer precision of time perception and precision of temporal processing in people with schizophrenia, with no differences in accuracy of time perception.**
Time perception	
30 studies, N = 2,017 *A large effect of poorer precision of time perception in people with schizophrenia;* 16 studies, N not reported, *g* = -1.17, 95%CI -2.29 to -0.05, *p* = 0.042 *A large effect of poorer precision of temporal processing in people with schizophrenia;* 6 studies, N not reported, *g* = -1.03, 95%CI -1.63 to -0.43, *p* = 0.017 *There were no significant differences in accuracy of time perception;* 17 studies, N not reported, *g* = 0.29, 95%CI -0.04 to 0.63, *p* = 0.084 Removal of outliers did not substantially change these results. Subgroup analysis of interval range found significant reductions in accuracy in the medium range (10sec-10mins), but not the ultra-short (<1sec), short (1-10sec), or large (>10min) ranges. There were significant reductions in precision in the ultra-short and short ranges, with no analyses conducted on medium or large ranges.	
Consistency	Authors report accuracy and precision of time perception were inconsistent, and precision of temporal processing was consistent.
Precision	Imprecise
Directness	Direct

Ueda N, Maruo K, Sumiyoshi T

Positive symptoms and time perception in schizophrenia: A meta-analysis

Schizophrenia Research: Cognition 2018; 13: 3-6

View review abstract online

Comparison	**Relationship between time perception and positive symptoms in people with schizophrenia.**
Summary of evidence	**Moderate quality evidence (small sample, consistent, precise, direct) finds a medium-sized association between poorer time perception and more severe positive symptoms.**
Time perception and positive symptoms	
A medium-sized relationship between poorer time perception and more severe positive symptoms; 4 studies, N = 101, r = -0.54, 95%CI -0.69 to -0.33, $p < 0.05$, I^2 = 33%, p = 0.22	
Consistency	Consistent
Precision	Precise
Directness	Direct

Zhou HY, Cai XL, Weigl M, Bang P, Cheung EFC, Chan RCK

Multisensory temporal binding window in autism spectrum disorders and schizophrenia spectrum disorders: A systematic review and meta-analysis

Neuroscience and Biobehavioral Reviews 2018; 86: 66-76

View review abstract online

Comparison	**Temporal binding in people with schizophrenia or autism vs. controls.**
Summary of evidence	**Moderate to high quality evidence (medium-sized samples, consistent, precise, direct) finds similar, large effects of impaired temporal binding in both schizophrenia and autism when compared to controls.**
Temporal binding	

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Large effects of more impaired sensory temporal integration in both schizophrenia and autism spectrum disorders; Schizophrenia: 8 studies, N = 305, *g* = 0.91, 95%CI 0.62 to 1.19, *p* < 0.001, I^2 = 32% Autism: 6 studies, N = 279, *g* = 0.85, 95%CI 0.54 to 1.15, *p* < 0.001, I^2 = 34%	
Consistency	Consistent
Precision	Precise
Directness	Direct

Explanation of acronyms

CI = Confidence Interval, Cohen's *d* and Hedges' *g* = standardised mean differences, I^2 = the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance), N = number of participants, *p* = statistical probability of obtaining that result

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Explanation of technical terms

* Bias has the potential to affect reviews of both RCT and observational studies. Forms of bias include; reporting bias – selective reporting of results; publication bias - trials that are not formally published tend to show less effect than published trials, further if there are statistically significant differences between groups in a trial, these trial results tend to get published before those of trials without significant differences; language bias – only including English language reports; funding bias - source of funding for the primary research with selective reporting of results within primary studies; outcome variable selection bias; database bias - including reports from some databases and not others; citation bias - preferential citation of authors. Trials can also be subject to bias when evaluators are not blind to treatment condition and selection bias of participants if trial samples are small[7].

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† Different effect measures are reported by different reviews.

Prevalence refers to how many existing cases there are at a particular point in time. Incidence refers to how many new cases there are per population in a specified time period. Incidence is usually reported as the number of new cases per 100,000 people per year. Alternatively some studies present the number of new cases that have accumulated over several years against a person-years denominator. This denominator is the sum of individual units of time that the persons in the population are at risk of becoming a case. It takes into account the size of the underlying population sample and its age structure over the duration of observation.

Reliability and validity refers to how accurate the instrument is. Sensitivity is the proportion of actual positives that are correctly identified (100% sensitivity = correct identification of all actual positives) and specificity is the proportion of negatives that are correctly identified (100% specificity = not identifying anyone as positive if they are truly not).

Weighted mean difference scores refer to mean differences between treatment and comparison groups after treatment (or occasionally pre to post treatment) and in a randomised trial there is an assumption that both groups are comparable on this measure prior to treatment. Standardised mean differences are divided by the pooled standard deviation (or the standard deviation of one group when groups are homogenous) that allows results from different scales to be combined and compared. Each study's mean difference is then given a weighting depending on the size of the sample and the variability in the data. Less than 0.4 represents a small effect, around 0.5 a medium effect, and over 0.8 represents a large effect[7].

Odds ratio (OR) or relative risk (RR) refers to the probability of a reduction (< 1) or an increase (> 1) in a particular outcome in a treatment group, or a group exposed to a risk factor, relative to the comparison group. For example, a RR of 0.75 translates to a reduction in risk of an outcome of 25% relative to those not receiving the treatment or not exposed to the risk factor. Conversely, a RR of 1.25 translates to an increased risk of 25% relative to those not receiving treatment or not having been exposed to a risk factor. A RR or OR of 1.00 means there is no difference between groups. A medium effect is considered if RR > 2 or < 0.5 and a large effect if RR > 5 or < 0.2[8]. lnOR stands for logarithmic OR where a lnOR of 0 shows no difference between groups. Hazard ratios

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measure the effect of an explanatory variable on the hazard or risk of an event.

Correlation coefficients (eg, r) indicate the strength of association or relationship between variables. They can provide an indirect indication of prediction, but do not confirm causality due to possible and often unforseen confounding variables. An r of 0.10 represents a weak association, 0.25 a medium association and 0.40 and over represents a strong association. Unstandardised (*b*) regression coefficients indicate the average change in the dependent variable associated with a 1 unit change in the independent variable, statistically controlling for the other independent variables. Standardised regression coefficients represent the change being in units of standard deviations to allow comparison across different scales.

‡ Inconsistency refers to differing estimates of effect across studies (i.e. heterogeneity or variability in results) that is not explained by subgroup analyses and therefore reduces confidence in the effect estimate. I^2 is the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance) - 0% to 40%: heterogeneity might not be important, 30% to 60%: may represent moderate heterogeneity, 50% to 90%: may represent considerable heterogeneity and over this is considerable heterogeneity. I^2 can be calculated from Q (chi-square) for the test of heterogeneity with the following formula[7];

$$I^2 = \left(\frac{Q - df}{Q}\right) \times 100\%$$

§ Imprecision refers to wide confidence intervals indicating a lack of confidence in the effect estimate. Based on GRADE recommendations, a result for continuous data (standardised mean differences, not weighted mean differences) is considered imprecise if the upper or lower confidence limit crosses an effect size of 0.5 in either direction, and for binary and correlation data, an effect size of 0.25. GRADE also recommends downgrading the evidence when sample size is smaller than 300 (for binary data) and 400 (for continuous data), although for some topics, these criteria should be relaxed.[9]

‖ Indirectness of comparison occurs when a comparison of intervention A versus B is not available but A was compared with C and B was compared with C that allows indirect comparisons of the magnitude of effect of A versus B. Indirectness of population, comparator and/or outcome can also occur when the available evidence regarding a particular population, intervention, comparator, or outcome is not available and is therefore inferred from available evidence. These inferred treatment effect sizes are of lower quality than those gained from head-to-head comparisons of A and B.

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