Title Page

Habituation, Part I. Design Choices in the Infant Habituation Paradigm: A Pre-registered Crowd-Sourced Systematic Review and Meta-Analysis

Keywords: habituation paradigm, systematic review, meta-analysis, infancy, 0-18 months, novelty preference

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Data, Materials & Code Availability. The sysrev projects for [training](#) and [data collection](#) are openly available. The full dataset and documentation are available for public use and can be downloaded from the project's [Open Science Framework \(OSF\) repository](#). All code for data cleaning and analysis associated with the current submission is provided as part of the same replication package. Any updates will also be published on the OSF and GitHub, and the final DOI cited in the manuscript.

Abstract

Methodological variations and inconsistency in reporting practices pose considerable challenges to the interpretation and generalizability of outcomes derived from the habituation paradigm - one of the most prominent methods for studying infant cognition. In a systematic review, we map out experimental design choices in habituation study samples aged 0-18 months using looking time measures. 2,853 records published in peer-reviewed journals between 2000-2019 were extracted from PsycInfo and Web of Science. 781 (27.4%) papers were deemed eligible after screening (Fleiss kappa = .60, 95%, CI[.40 - .80], 6 blind raters). We adopt a collaborative, multi-lab approach for crowd-sourced data collection involving raters from the developmental research community. In a meta-analysis, we assess the impact of habituation detection criteria on the novelty effect size, moderated by age. Our results will inform a detailed evaluation of experimental designs and a set of recommendations to improve research and reporting practices in infant habituation research.

Keywords: habituation paradigm, systematic review, meta-analysis, infancy, 0-18 months, novelty preference

Habituation, Part I. Design Choices in the Infant Habituation Paradigm: A Crowd-Sourced Systematic Review and Meta-Analysis

Introduction

The habituation paradigm is among the most prominent methods for studying infant cognition (Colombo & Mitchell, 2009; Kellman & Arterberry, 1998; Oakes, 2010). Experimental designs and protocols, as well as reporting practices, vary greatly between studies. These methodological variations and lack of consistency in reporting practices pose considerable challenges to the interpretation and generalizability of the outcomes derived from habituation studies. Precisely characterizing the habituation process is further hindered by procedural variations with unknown effects on the outcomes (Kucharský et al., 2022). As a result, some of the basic characteristics of the paradigm remain elusive, most notably concerning the factors that determine the novelty effect (Hunter & Ames, 1988), as well as the characteristics of the habituation process itself that affect optimal experimental design choices (Colombo & Mitchell, 2009). In this registered report, we perform a systematic review and meta-analysis of experimental design and reporting practices over the past 20 years of the infant habituation paradigm and weigh the impact of - potentially arbitrary - methodological design choices on the presence and strength of the novelty effect. Before discussing the current study in more detail, we briefly sketch out the workings of the habituation paradigm and its relevance to the field of infant research.

The Habituation Paradigm

Investigating mental processes in infancy has advanced substantially as a consequence of the development of methods that indirectly quantify infants' interest in a stimulus, one of the most widely used being the habituation paradigm (Bornstein, 1985; Fantz, 1964; Saayman et al., 1964). This method allows researchers to infer whether infants can discriminate between two (classes of) stimuli, by capitalizing on the idea that infants are more readily interested and responsive towards stimuli that are novel to them, and less so towards stimuli that they have encountered repeatedly.

During a typical habituation procedure, infants' behavioral or neurophysiological responses towards a certain stimulus are monitored. Commonly measured responses are, for instance, sucking, looking time, head orientation, and neurophysiology (Fennell, 2012). In this paper, we focus on looking behavior because it is a widely measured response across infancy (Clohessy et al., 2001; Johnson & Tucker, 1996; Plude et al., 1994) that is specifically directed towards or away from a particular stimulus in the visual environment rather than representing a general arousal state. Our findings are nevertheless likely to generalize to other response modalities because the basic workings of the underlying habituation mechanism are supposedly the same (Rankin et al., 2009).

The fundamental assumption of the habituation method is that over repeated presentations, an infant gradually loses interest in what is being displayed, which is in turn reflected in the decreasing rate, duration, and intensity of the visual attention response (Aslin, 2007). Once response attenuation has occurred, a recovery of attention should be observed towards any new, unfamiliar stimulus - that is, if the infant perceived it as such. This recovery of

interest is taken as evidence that the infant can discriminate between the novel and the familiar stimulus (Sokolov, 1963). In this study, we define habituation as the decreasing response to a stimulus (or a stimulus category) over repeated exposure. A dishabituation response (also known as a novelty preference), we define as the increasing response to an unfamiliar stimulus (or a stimulus category) following successful habituation. These definitions encompass studies that use the habituation and dishabituation responses as a means to investigate other cognitive phenomena such as discrimination (Streri & Pecheux, 1986) and category learning (Mareschal et al., 2000; Gureckis & Love, 2010), among others. Procedures that yield measurable (dis-)habituation processes thus include protocols that allow to quantify as well as directly compare habituation and dishabituation from looking responses to familiar versus novel stimuli (e.g., familiarization procedures).

The habituation procedure is infant-friendly, versatile and relatively easy to implement because it takes advantage of the natural tendency of infants - and to a great extent among other species - to direct attention towards meaningful stimuli in the environment (Fantz, 1957, 1958, 1961; Fitz-Gerald, 1963; Rankin et al., 2009; Saayman et al., 1964). In cognitive models, attention is thought to reveal steps in information processing such as selection among competing stimuli, stimulus representation, or comparison between the environment and contents of memory (Bornstein & Colombo, 2012). To this day, hundreds of habituation studies have been conducted to investigate the mental processes of infants. Streams of research such as language learning (e.g., Bijeljac-Babic et al., 2016; Byers-Heinlein et al., 2013; Fennell & Werker, 2003; Kajikawa et al., 2006), face perception (e.g., Anzures et al., 2009; Damon et al., 2016; Sakuta et al., 2014; Xiao et al., 2015), numerical cognition (e.g., Brannon, 2002; Lipton & Spelke, 2003, 2004; Xu et al., 2005), rule learning (e.g., Bulf et al., 2011, 2015; Frank et al., 2009; Kirkham et

al., 2007), emotion processing (e.g., Addabbo et al., 2018; Brenna et al., 2013; Hock et al., 2017; Ichikawa et al., 2014), social development (e.g., Henderson et al., 2013; Henderson & Woodward, 2011; Kelly et al., 2007), intelligence (e.g., Kavšek, 2004; McCall & Carriger, 1993; Slater, 1997), memory (e.g., Dupierrixx et al., 2015; Jones et al., 2011; Oakes & Kovack-Lesh, 2013; Zosh et al., 2011), among others, were able to make considerable progress in understanding sociocognitive development using the habituation paradigm. Yet, best practices in designing habituation studies are not firmly established and in concordance with methodological and technological developments in infant research, nor is our understanding of habituation as a cognitive process in infancy (Colombo & Mitchell, 2009; Kucharský et al., 2022; Sirois & Mareschal, 2002).

Understanding Experimental Design Factors in Relation to the Habituation Process

Despite a wealth of research into habituation, which factors contribute to producing either novelty or familiarity effects is still debated (e.g., Bergmann et al., 2019). Hunter and Ames (1988) offered a number of proposals about putative factors that could influence whether a familiarity or a novelty preference can be expected (these will be empirically assessed in the multi-lab project Many Babies 5: <https://manybabies.github.io/MB5>). Here we distinguish between three types of factors: 1) the design factors of the habituation phase, 2) the level of habituation, determined by the habituation detection criterion, and 3) age, which has shown to interact with the course and rate of the habituation process (Colombo, 2002; Colombo & Mitchell, 2009; Colombo et al., 1987; Colombo et al., 2004; Hood et al., 1996; Slater et al., 1996). These factors are discussed in turn, after we briefly cover the goals researchers typically have with the habituation phase of the experiment.

Habituation/dishabituation procedures here are considered those involving 1) trials presenting the same stimulus sequentially during a training phase, and 2) test trials presenting a novel stimulus and the familiar. The goal of the habituation phase is that infants become less responsive towards a particular set of stimuli without disengaging from the task altogether due to fussiness or distress, for instance. The necessary balance between these two design demands makes optimal design choices important but very complex and context-specific.

Typically, habituation studies make use of some criterion to determine whether infants have indeed arrived at a state of habituation - these criteria are discussed below. The application of any criterion suffers from false positives (i.e., reaching the criterion without being habituated) and (false) negatives (i.e., not reaching the criterion before getting fussy or distressed), and a well-performing criterion should reliably discriminate between the looking time distributions of the infants who did and did not habituate. A habituation criterion that systematically yields small effect sizes (i.e., subtle differences in the looking times towards the novel versus the familiar stimuli) bears a higher risk of false positives and false negatives - especially in combination with other design factors that diminish the reliability of the measurement - because the looking time distributions of habituators and non-habituators in the sample will overlap more strongly. A meta-analytic approach is thus especially suitable for quantifying the relationship between habituation criteria and the effect sizes they tend to produce, while keeping the effect of other design factors fixed across infant habituation studies.

Whereas most studies anticipate a novelty preference during the post-habituation (i.e., test) phase, some report familiarity preferences (e.g., Fiser & Aslin, 2002; Johnson et al., 2009). The goal of the habituation phase design, however, is to maximize the likelihood of completing the habituation process - manifested as a novelty preference at the post-habituation phase

(Hunter et al., 1983; Hunter et al., 1982; Oakes, 2010). Thus, studies reporting on familiarity preferences likely employ design practices that tap into an earlier stage of the habituation process (Sirois & Mareschal, 2002). Below we discuss some of the design choices encountered in habituation studies.

Structural Design Factors

A typical habituation study involves the subsequent presentation of trials of one type - the to-be habituated stimulus/i, followed by a testing phase where looking times to novel and familiar stimuli are contrasted. Both novel and familiar trials need to be presented at post-habituation in order to assess the dishabituation effect (Oakes, 2010) because presenting only novel trials at post-habituation may be, at least in part, affected by a regression to the mean (Ashmead & Davis, 1996; Dannemiller, 1984). Major design choices regarding the structure of the habituation task thus are:

1. the minimum and maximum duration of each trial,
2. the minimum and maximum number of trials that each infant is exposed to,
3. the number and order of test trials (familiar versus novel first, random versus blocked),
4. the number of trials to present before initiating the post-habituation phase (also covered in the discussion of habituation detection criteria below).

Stimulus Characteristics

A crucial determinant of looking times is the information value that the stimuli presented as novel and familiar carry (Kidd et al., 2012; Richards, 2010). In this study, the focus is on structural factors of the habituation paradigm and we will hence leave factors such as stimulus type and complexity aside - also because these are hard to quantify and compare across a large

set of studies. By abstracting over between-study variation in stimulus type and complexity, we are able to include a very large number of studies rather than constraining ourselves to a subset of studies using comparable stimuli. To provide a starting point for future investigations aiming to address the relation between stimulus characteristics and habituation performance, we gather superficial descriptives on the variability of stimulus characteristics such as stimulus modality and static versus dynamic presentation, as well as the page numbers on which images and schematics of the stimulus displays were reported in the original manuscripts so that these can be compiled into a database.

Looking Time Detection Methods

Another important factor pertaining to the precision and reproducibility of infant looking times obtained from habituation experiments is the looking time detection method. Earlier research using looking measures has relied on manual coding techniques (Aslin & McMurray, 2004; Oakes, 2012), in which at least one but preferably multiple raters record the infant's looking behavior either *online*, during the experiment, and/or *offline* from a video recording. Recent advances in eye-tracking are becoming increasingly more prevalent in infant research, making looking time recordings automated, objective, and substantially more spatially and temporally precise (Aslin & McMurray, 2004; Gredebäck et al., 2009; Hunnius, 2007). Despite considerable perks, however, fully automated scripts are still not reliably implemented across habituation procedures (e.g., Cong et al., Oakes, 2012).

A potential drawback of automated methods such as eye-tracking is that obtaining a signal of sufficient quality can be challenging, especially with young infants, which could lead to higher experimental attrition than what is typically observed with manual coding techniques¹. Habituation procedures that lead to higher experimental attrition due to fussiness can systematically bias samples (Slaughter & Suddendorf, 2007) and are therefore less advisable. Using manual looking detection methods, mean attrition rates (overall and due to fussiness) estimated from 143 habituation studies have been reported at 22.6% and 14.1%, respectively (Slaughter & Suddendorf, 2007). In contrast, a recent application of an automated face analysis tool to measure the looking times of 5 to 8-month-old infants from video footage yielded about 30% missing data relative to manually coded frames (Chouinard et al., 2019). To date, we are not aware of any systematic comparisons between eye-tracking and manual coding techniques in infant (habituation) samples; hence, we provide descriptives on current practices regarding the degree of automation in habituation experiments (such as looking time detection and stimulus presentation methods) and their relation to experimental attrition rate, as well as the strength of the novelty effect.

¹Looking time measures are further sensitive to the specific data parsing algorithms and individual differences in data quality (Hessels et al., 2015; Hessels & Hooge, 2019; Wass et al., 2014), though these issues are continuously being addressed (Hessels & Hooge, 2019; Leppänen et al., 2015; Schlegelmilch & Wertz, 2019; van Renswoude et al., 2018; Wass et al., 2013).

Habituation Detection Criteria

The single most important (and often discussed!) design factor is the use of a habituation criterion (Oakes, 2010). The logic of the habituation paradigm is that a decrease in interest by the infant signals that they have somehow processed the stimulus sufficiently to be able to discriminate it from other stimuli. The purpose of a habituation detection criterion is to then determine *when* a significant loss of interest has occurred in the infant such that the post-habituation phase of the experiment can be initiated. A number of criteria have been applied throughout the literature that we broadly group under decrement, fixed, and model-based criteria.

Decrement Criteria.

Probably the most commonly applied class of criteria are the *decrement* criteria (Horowitz et al., 1972), which detect habituation when the ‘final looking time’ ‘decreases’ below a certain percentage of the ‘baseline looking time’. A number of choices can be made in applying this criterion. First, the ‘baseline looking time’ can be defined as the looking time on the first trial or as an average of the first few trials; a common choice is to average across the 3 initial trials (Ashmead & Davis; Oakes, 2010) although other numbers certainly occur (e.g., Domsch et al., 2009; Galle et al., 2015). Similarly, the ‘final looking time’ is defined either as the looking time at the last trial or an average across a set of recent trials (Oakes, 2010). The ‘decrease’ in looking time is frequently set at a 50% decrease from the baseline to the final looking times (Ashmead & Davis, 1996; Cohen, 2004), but other percentages occur as well (e.g., Flom & Pick, 2012). Specifying these three variables already makes up for a large variability in the criteria being applied. One of our goals here is to report on how commonly different versions of the decrement criterion are encountered and what the consequences for the magnitude of the reported novelty effects are.

Yet another variant of the decrement criterion worth mentioning uses a similar definition of the looking time decrease and the final looking time but an alternative definition for the baseline looking time. Rather than the initial looking time, the maximum looking time (also referred to as the *peak* look) serves for calculating the percentage decrease from the final looking time. The reasoning here is that an infant's interest towards the stimulus can show an increase preceding the typical looking time decline pattern (Gilmore & Thomas, 2002; Hunter & Ames, 1988). Similarly to the initial and final looking times, the maximum looking time can be derived as an average across a single trial or a set of peak look trials (Colombo & Mitchell, 1990, discuss this variant). Another variation is to apply the criterion on the average looking time accumulated across all previous trials in the habituation phase.

Fixed Criteria.

Under *fixed* criteria fall all procedures that require all infants to accrue a fixed number of trials or a fixed looking time before the testing phase can be initiated. Studies using fixed criteria are often referred to as familiarization studies, but for our purposes can still be considered habituation paradigms if a novelty effect is expected in the post-habituation phase (e.g., Schlingloff et al., 2020).

Model-Based Criteria.

Other criteria for determining whether and when infants have habituated have been proposed too but are seldomly used. In particular, several authors proposed to substitute the classic decrement and fixed criteria with *model-based* criteria (Ashmead & Davis, 1996; Thomas & Gilmore, 2002). The authors defined mathematical models of the ideal habituation curve and proposed to use this to estimate when infants have habituated. Beyond reporting on the

frequency of use, it is outside the scope of the current paper to discuss the application of these approaches (which is done in detail by Kucharský et al., 2022).

Relevance of Habituation Detection Criteria to the Novelty Effect and Attrition in Studies.

Infants who have not fully habituated exhibit a familiarity preference (Hunter & Ames, 1988; Hunter et al., 1982; Roder et al., 2000; Rose et al., 1982; Sirois & Mareschal, 2002) and therefore contaminate the overall novelty effect if included in the analysis. In an often-cited paper, Oakes (2010) suggests several practices regarding the *stringency of the habituation detection criterion*, the use of *sliding over fixed windows*, and the *maximum number of trials*, among others, that are all thought to maximize the number of truly habituated infants in the analysis. Specifically, Oakes advises the use of a stringent criterion, operationalized as the 50% decrement criterion applied on a sliding window of three trials. She further proposes that 1) criteria requiring a larger decrement from the initial looking times are thought to yield larger effect sizes, though this relationship should be non-linear because criteria that are too strict would result in more infants who did habituate but failed to reach the criterion (i.e., false negatives), 2) using sliding over fixed windows would result in lower attrition and false negatives because they pinpoint more precisely the timing of reaching the habituation criterion, 3) a lower number of maximum trials would bear a lower chance of attrition due to fussiness overall and a lower risk of the infant reaching the habituation criterion by chance. One of our goals is to assess whether these recommendations are indeed borne out by evidence.

Crowd-Sourcing as a Data Extraction Approach for Review Papers in Infant Research

Over the past decades, the importance and utility of large-scale collaborative efforts have gained increasing recognition across scientific disciplines, including infant studies (Frank, et al. 2017) - a field of research that is frequently confronted with the challenge of answering research questions in underpowered samples (Bergmann et al., 2018). This has inspired efforts such as ManyBabies (<https://manybabies.github.io>; Byers-Heinlein et al., 2020) and MetaLab (Gasparini et al., 2021; Tsuji et al., 2014; 2017) that aim to answer substantive questions with a greater degree of certainty. Whereas ManyBabies focuses on multi-lab replication studies, MetaLab offers repositories, templates, and tools for community-augmented systematic reviews and meta-analyses on central research themes in developmental linguistics and psychology.

Despite that a great body of empirical work using the habituation paradigm has been accumulated, very limited resources have been dedicated to help researchers make informed decisions about features of the experimental design that would allow them to assess the substantive research question at hand. Review papers typically aim at answering a substantive question and thus focus on a narrow, homogenous subset of literature. In contrast, a large body of literature needs to be taken into account to evaluate procedural and domain-specific variations across multiple disciplines that rely on the same phenomenon. Using crowd-sourcing as a general approach to review papers can greatly improve the replicability and generalizability of infant studies by allowing the systematic synthesis, meta-analysis, and updating of a much larger body of literature than what is typically feasible within individual research groups with localized expertise. Here we outline and implement a crowd-sourcing data extraction workflow to a large dataset of infant habituation studies with the hope that others can adapt and build upon it. Similar crowd-sourced data extraction approaches for systematic reviews and meta-analyses have been

applied to gene expression data in biomedical sciences (Mortensen et al., 2017; Strang & Simmons, 2018) and can be further applied to other comparable problems involving some sort of manual data extraction (e.g., corpus data).

The Current Study: Systematic Review & Meta-analysis

In a systematic review, we map out experimental design choices used in peer-reviewed habituation studies published in the period 2000-2019, including - but not limited to - the criteria applied to determine whether habituation has taken place. This part of the study can be considered a scoping review as it sets out to examine the range and nature of research activity to its fullest extent (Arksey & O'Malley, 2005). In a follow up meta-analysis, we assess how current experimental design practices in habituation studies relate to the research outcomes, with a specific focus on the association of these practices with 1) attrition rates and 2) the size of the novelty effect. Because the evaluation of study design choices is the central goal of this paper, certain features of the critical appraisal process (e.g., risk of bias assessment) common to systematic reviews and meta-analyses are postponed until after data extraction. To increase the reliability of the results, we use a crowd-sourced workflow in which raters willing to contribute to the data extraction process are recruited from the wider community of developmental researchers and each paper is randomly assigned for blind data extraction to at least two raters who subsequently discuss and resolve coding disagreements. Based on the descriptive (scoping), systematic review, and meta-analytic goals formulated below (and under Appendix A), we devise a set of recommendations for habituation studies that aim to provide researchers with an empirical base for designing their experiments, and to improve reporting standards.

Descriptive Goals & Hypotheses

In the descriptive analysis, we report on the distributions of current experimental design practices with regard to stimulus characteristics, the habituation task structure, presentation and response detection methods, and evaluate the extent to which the recommendations regarding habituation detection criteria and trial number proposed by Oakes (2010) are implemented. Further, we provide an indication of the general data quality among the habituation studies included past the screening phase, such as descriptives on dropout rates and on inter-rater reliabilities and blind coding practices for the studies using manual coding of looking time.

Analyses of Attrition Rates: Goals & Hypotheses

Oakes (2010) suggests that more stringent habituation criteria will lead to fewer “habitutors”, but failing to exclude “non-habitutors” may compromise the robustness of the novelty effects. Following the reasoning that habituation protocols aim to maximize the proportion of infants that reach habituation from the total number of infants included at the post-habituation phase (Hunter et al., 1983; Oakes, 2010), we evaluate empirically which experimental habituation design choices predict attrition caused by failure to meet habituation criteria. More stringent experimental designs, however, may also lead to higher experimental attrition (e.g., due to fussiness, etc.) which affects data quality. Thus, we need to evaluate which experimental design choices predict experimental attrition separately from habituation attrition - whereas the interpretation of habituation attrition is somewhat ambiguous because lower habituation attrition rates can presumably produce smaller novelty effects, minimizing experimental attrition is desirable in all measurement contexts. Figure 1 summarizes the relation among the types of attrition we analyze, highlighting that habituation attrition needs to be interpreted in tandem with the size of the novelty effect.

Figure 1*Breakdown of Overall Experimental Attrition Rate.*

Note. This diagram summarizes the types of attrition distinguished in this study. Experimental attrition is caused by any drop-outs from the experiment, due to fuzziness, failure of experimental equipment, experimenter error, or other reasons. Experimental attrition is generally undesirable and procedures should aim to minimize it. Habituation attrition is caused by the infant not meeting the habituation criterion. This attrition is not necessarily undesirable as it can help achieve larger novelty effects (Oakes, 2010).

As discussed earlier, automatic response detection methods hold the promise to maximize measurement precision and the reproducibility of results, but whether their use introduces higher experimental attrition is unclear. We therefore compare the experimental attrition and attrition due to failed habituation as a function of the response detection method: eye-tracking versus manual coding.

Meta-Analytic Goals & Hypotheses

In the meta-analysis, we focus on the relation between habituation criteria and the magnitude and direction of the effect size. Following the logic that if the habituation procedure is

successfully implemented, novelty should be expected (Hunter et al., 1983; Hunter et al., 1982), we ask three main questions:

1. What is the average size of the novelty effect during the post-habituating phase?
2. How are detection criteria related to the strength of the novelty effect?
3. How is age related to the strength of the novelty effect?

The specific hypotheses and statistical tests designed to answer these questions are summarized in Appendix A and under Modeling in the Results section. We compare across variants of percentage decrement versus fixed-type criteria used in habituation studies in predicting the presence and magnitude of the novelty effect as a function of age. and then zoom in on the evaluation of specific criteria. Variation in the sensory modality (visual, auditory, visual-auditory) in which the habituation stimuli were presented, as well as whether the habituation stimuli were presented statically versus dynamically will be incorporated as nuisance variables in order to control for between-study differences. Further, as our definition of habituation is relatively inclusive and will result in a pool of studies that test other phenomena than a simple novelty/familiarity preference, we add a nuisance variable which codes whether or not the stimulus in the post-habituating phase is identical, or of the same type or category to the stimulus shown during the post-habituating phase. This allows us to distinguish between simple habituation studies and studies that also tap into further cognitive phenomena (e.g., categorization).

Method

Systematic Search

Search Strategy & Information Sources

The search strategy and syntax were devised in consultation with a librarian. We searched for peer-reviewed papers published in the period 2000-2019 on the topic of habituation in infancy (database-defined as 0-23 months), either in combination with a mention of a looking behavior response or experimental study design to reduce noise in our results. A recency bias is introduced by the time limits, which is acceptable for our study purposes to map out current research practices. Because the search strategy aimed to maximize the representativeness of the retrieved records, the systematic search was performed across two major databases in the field of psychology - PsycINFO and Web of Science, expecting that the majority of developmental science disciplines employing the habituation paradigm in human infants are to be found there. The database searches were performed on May 21, 2020. The search syntax is available under Appendix B and online on the project's [Open Science Framework \(OSF\) repository](#). Out of 3,858 results from the systematic search, 1,005 papers were manually removed in Zotero (v. 5.0.89, Ahmed & Al Dhubaib, 2011): 996 duplicates, 2 retracted papers, 7 “early access” papers. To update the search results with more recently published papers, we will rerun the same search once more immediately before the start of the data collection stage. The records of “early access” papers will be screened at this stage too in order to add the corresponding volume/issue details.

Study Selection & Eligibility Criteria

After de-duplication, the titles and abstracts of the remaining 2,853 papers were screened simultaneously for relevance by 6 blind raters (inter-rater reliability Fleiss kappa = .60, 95% CI [.40 - .80]) using the systematic review web application Rayyan (Ouzzani et al., 2016). To maximize consistency among raters during the screening process, articles were excluded in a hierarchical manner following the exclusion reason order provided in Figure 2.

We focused on including records describing original data on typical development. We further limit the scope of our study to 1) designs in which habituation is at least indirectly measurable or measured (e.g., measuring looking times on repeating trials), and 2) dishabituation is measurable (i.e., looking times toward the familiar stimulus/i in the post-habituation phase can be directly compared to looking times toward the novel stimulus/i in the post-habituation phase, as well as toward the familiar stimulus/i in the habituation phase; visual paired comparison and head turn preference study designs are thus excluded). Due to inconsistent use of terminology¹, researchers may occasionally report using a familiarization paradigm whereas a habituation paradigm is actually being used. To increase the number of relevant habituation studies in our sample, records reporting on familiarization protocols were included as long as 1) more than one familiarization trials were presented during the habituation (pre-test) phase, and 2) novel stimuli were presented in the post-habituation (test) phase. During data extraction, the portion of papers in which researchers had an a priori hypothesis for a familiarity preference (and hence likely designed the procedure to target an earlier stage of the habituation process) will be excluded. Habituation protocols presenting tactile stimulation as the habituation stimuli were excluded because such protocols are very unlikely to elicit and measure changes in the infants' looking behavior responses that are comparable to those towards habituation stimuli in other modalities.

¹To maximize the amount of relevant search results, we added several synonymous key terms that are often used in the context of habituation/dishabituation procedures (e.g., discrimination, familiarization, visual preference, etc.). Nevertheless, studies that rely on habituation/dishabituation designs but do not explicitly mention "habituation" or any of the related key terms are omitted in our results.

Studies using a head-preference to infer whether infants have habituated were also excluded. 781 (27.4%) papers describing original data from habituation studies using looking behavior measures in infants between 0 and 18 months were selected for data extraction. The PRISMA flow chart (Figure 2) outlines the number of papers at each step of the screening process.

Figure 2

Study Identification Stages at Stage I Registered Report Outlined in the PRISMA Flow Diagram.

Reporting Guidelines

Here we use the PRISMA 2020 (Page et al., 2021) and the NIRO (Non-Interventional, Reproducible, and Open Systematic Reviews; Topor et al., 2021) reporting guidelines for systematic reviews.

Developing the Coding Scheme

Prior to pre-registering this study, we conducted a feasibility pilot study that aimed to 1) select the set of variables on which data are extracted for our analyses, 2) define a variable coding scheme, and 3) devise a procedure for coding the data. Throughout, we were assessing the reliability of the coding to identify and resolve problems with the current coding.

The initial feasibility study followed an iterative procedure. First, an initial list of variables that were coded and their definitions was implemented in a spreadsheet. Then, a random set of articles were selected and distributed among the authors of this study for initial coding. During this stage, the coders were able to communicate and exchange their thoughts on the coding and note down issues that were encountered (e.g., a missing level in a categorical variable). A new coding sheet was developed based on the initial experiences. Then, a set of 70 articles identified in the screening as relevant was distributed among seven raters such that each article was rated by at least three raters (this resulted in each rater being assigned 30 articles). The seven raters coded the articles independently to assess the reliability of the coding on all selected variables. Following the reliability results, additional changes were made to the coding scheme to standardize the data extraction of multiple experiments, experimental conditions, or age groups reported in the same paper, and the distinction between various habituation criteria, as well as introducing data input validation to minimize reporting errors. During this stage of the project,

we developed the coding manual following the PRISMA-P guidelines for systematic review and meta-analysis protocols (Moher et al., 2015) and prepared an online project for crowd-sourced data collection described below.

Crowd-sourced Data Collection

Data extraction from all papers included past the screening stage will be done using crowd-sourcing. Specifically, we will attract collaborators through developmental research mailing lists (e.g., the Cognitive Developmental Society (CDS), the International Congress of Infant Studies, and the ManyBabies mailing lists), inviting them to contribute to the data extraction as raters. Raters who subscribe to help with coding the articles will be invited to a Slack workspace for faster communication, and will receive further instructions with the data extraction workflow. We will employ data validation and provide coders with a coding manual to maintain the quality of the coding reliability, keeping the data organized and clean. Raters will be included as co-authors in the stage II report.

Use of sysrev

Sysrev (sysrev.com) is an online platform that facilitates the systematic reviews of documents with multiple contributors. Articles identified in the screening stage will be uploaded to the sysrev project as .pdf files. Contributing raters will be required to create a (free) account on sysrev to log in. Sysrev will then automatically present the raters with articles that are not yet coded by more than one other rater. Raters will then proceed with coding the article directly on the sysrev platform. To limit human-error and ambiguity in the data extraction, we have implemented, where applicable: 1) multiple-choice items, 2) data validation checks that request the user to provide valid variable values whenever the input does not match the expected (e.g.,

checking whether user-entered values for numeric variables are indeed numeric), 3) the possibility to specify that data on the item is missing. Sysrev keeps the review in a database from which the data can be extracted in various standard formats.

Maintaining Reliability

To maximize inter-rater reliability, raters are provided with 1) a coding manual with instructions on how to extract information on the data items (including examples of edge-cases identified during the pilot stage) and how to resolve disagreements with other raters, 2) a separate sysrev project for training, containing five papers coded by consensus to help raters get acquainted with the data extraction process while using the coding manual. Upon joining the project, raters will be given access to the [training](#) and [data collection](#) sysrev projects along with the project's OSF repository containing the coding manual and the pdf's of the five training papers with the data extraction process annotated. The coding process will be performed incrementally to maximize the number of raters per article. The data will be subsampled by publication date in 5-year batches, prioritizing more recent reports because evaluating current practices is our primary focus. This results in the following record distribution: 188 records for 2015-2020; 230 for 2010-2015; 194 for 2005-2010; 169 for 2000-2005. Depending on the availability of contributing raters, we will determine whether each paper will be coded by at least two or at least three raters in the data collection sysrev project, and whether we let sysrev assign new raters with papers that have been already coded by at least one or two other raters respectively. This way, we hope to further maximize the number of raters per paper while making sure that raters coding the same papers are involved in the project at approximately the same time.

After completing the blind coding in the current batch, the data will be downloaded and analyzed for inter-rater agreement and specific disagreements. After the results are known, raters will be asked to resolve any disagreements with other raters by communicating via Slack or otherwise. For data items on which consensus is not reached, raters will inform the project coordinators, who will assign an additional coder to that article. The final value will be taken on a majority vote basis. If the disagreement could not be resolved even then (e.g., when the vote count is 1-1-1 for three alternative options), the project coordinators will then take the final decision on how to resolve the coding. At stage II, we will report on inter-rater reliability metrics, the variables on which disagreements arose, and the number of disagreements that required resolution by project coordinators. The analysis of inter-rater agreement after each batch will be reported in the supplementary material, alongside an exploratory analysis studying whether the inter-rater reliability increased with increasing experience of the raters, providing some additional insights into the novel methodology of crowd-sourced review.

Recovering Missing Effect Size Information

The author(s) of studies for which essential data for computing the effect size is missing will be contacted. By failure to recover these data prior to initiating the meta-analysis, the effect size variables for these studies will be treated as missing.

Analysis Plan

The overview of the research questions, hypotheses, statistical analyses, and interpretation is provided in Appendix A.

Dependent and Independent Variables

An overview of the dependent and independent variables is provided separately for the descriptives (Table 1), and the meta-analysis and analyses of attrition rates (Table 2). The variables either overlap with or are composites of data items used for data collection in sysrev.

Descriptive Analyses

Before conducting any inferential statistics, the report will provide descriptive statistics and plots for all variables listed in Table 1. Categorical variables will be summarized in frequency tables, and continuous variables via summary statistics. These will be used to describe the typical trends and practices in habituation studies, with a focus on habituation criteria and their variations. Descriptive summaries will be also provided on the variability of experimental attrition rate (overall, due to fussiness, versus other causes lumped together), as well as the attrition rate due to a failed habituation phase (i.e., the infants excluded due to not meeting the habituation criterion). These summaries will be presented overall, as well as separately for distinct categories of presentation mode and looking time detection method.

Analyses of Attrition Rates

Some design choices may affect data quality. The current study focuses only on a small portion of possible data quality issues that may arise in infants research in general, and habituation experiments in particular (see Appendix A). Specifically, we will investigate whether there is any relationship between various design choices and the experimental attrition rate (i.e., whether there are any designs that are associated with fewer drop-outs). To this end, a binomial regression will be used with predictors corresponding to the degree of automation in the experiment: 1) presentation mode, 2) looking time detection method, and other variables such as: 3) stopping rule, 4) the maximum number of habituation trials) stimulus modality, and 6) average

age, and a dependent variable “N drop-out total” out of “original sample N”. Coefficients associated with a p-value less than 0.01 will be considered as statistically significant.

The attrition rate due to a failed habituation phase will be modeled with the same binomial regression, but with “N drop-out habituation” as the dependent variable. A Bayesian binomial regression will be used as a robustness check.

Whereas experimental attrition is generally undesirable, it is expected that a certain level of habituation attrition can lead to more robust results (Oakes, 2010). Therefore, while the desired outcome for the experimental attrition is to pinpoint which practices are related to lower attrition rates, factors related to the habituation attrition rates may need to be interpreted with the results of the meta-analytic results on the effect sizes (see below).

Meta-Analysis

Calculating Effect Sizes from the Extracted Statistics

The primary meta-analysis is based on the subset of studies that performed a comparison between novel and familiar stimuli in a within-subject design. The effect size of interest is the within-subject standardized mean difference (Cohen, 1988) - an effect size that reflects the standardized effect per participant, instead of the standardized difference between two measurements such as the more traditional Cohen’s *d* (Dunlap, et al., 1996, Moris & DeShon, 2002; see Additional Analyses section). This decision is based on the fact that the majority of studies use a within-subject design to increase the power for detecting an effect, and that the novelty-familiarity preference is typically thought of as the average looking time difference between novel and familiar stimuli within the same individual, rather than the average difference between novel and familiar stimuli between participants.

The effect size of interest will be computed from the t -statistic and the associated degrees of freedom df as follows:

$$d_z = \frac{t}{\sqrt{df + 1}}$$

The standard error of the effect size will be computed using the equation A1 from Morris & DeSchon (2002):

$$se_d = \sqrt{n^{-1}(df/(df - 2)) (1 + nd^2) - d^2/c(df)^2},$$

where $c(df) = 1 - 3 / (4df - 1)$. The df in both equations is equal to $df = n - 1$, where n is the number of participants in the study.

When an F-test is reported, the F-statistic will be converted to a t-statistic before converting it into the effect size using the formulas above.

Assessing Publication Bias

Publication bias will be assessed using standard procedures, as well as modeling approaches. Before analyzing the data using a meta-analysis, we will visualize the relationship between the effect size and standard error using a funnel plot. Further, we will compute the Bayesian Kendall's rank correlation test (van Doorn et al., 2018; 2019) to assess whether the standard errors and effect sizes correlate with each other. In case the Bayes factor favors the null hypothesis by at least a factor of three, we will conclude that there is low risk of publication bias. In case that the Bayes factor favors the alternative hypothesis by at least a factor of three, we will conclude that there is high risk of publication bias. We will also compute the Egger's test to assess the robustness of the correlation result. Additional analyses such as PET-PEESE meta-analysis selection models and robust meta-analysis (Maier et al., 2020) will be run as exploratory analyses in case of doubt over the robustness of the results against publication bias. In case of a

high risk of publication bias, the meta-analytic models described in the Modeling section below will be limited. The models will be run anyway, but the results will be included only in the Supplementary materials and no conclusions will be drawn from these models. Instead, selection models and robust meta-analyses will be interpreted in the main text as exploratory analyses.

Modeling

Studies or conditions for which authors expected familiarity preference or a null result will be excluded from the primary analysis. First, fixed effects meta-analysis and random effect meta-analysis will be run to determine the average effect size of the novelty effect, the choice of fixed or random effects will be based on the omnibus test for heterogeneity. However, the primary meta-analysis will be a frequentist meta-regression. The variables used for predicting the size of the effect will be: 1) average age of the sample and 2) the stopping rule (dummy coded; fixed number of trials and fixed looking time are combined into one category, all three decrement criteria are combined into another category, and “other” with “model-based” criteria will be combined into the “rest” category). As nuisance variables, 1) stimulus modality (dummy coded), 2) presentation mode (dummy coded), and 3) identical stimulus (dummy coded) will be included in the model. The identical stimulus variable is included to distinguish studies whose focus is more constrained on the phenomenon of habituation by presenting exactly identical stimulus during the entire experiment from studies that involve ancillary phenomena (such as categorization) by letting the stimulus vary within a type or a category over the course of the experiment. For the main hypotheses, the coefficients of age and stopping rule will be tested individually at the $\alpha=0.01$ level against the null hypothesis that the coefficients are zero.

The effect of age is hypothesized as positive - therefore it will be tested with a one-sided test, and will directly answer the research hypothesis that age relates to the strength of the

novelty effect. The effect of stopping rule is represented by multiple coefficients, each representing one category of the stopping rule criteria. We will conduct pairwise comparisons between the three combined categories (“fixed”, “decrement”, “rest”) of the stopping rule. We do not have directional expectations regarding these pairwise comparisons.

If the p-value associated with the coefficient for the decrement criteria category is below 0.01, a follow-up analysis will be run to provide additional detail as to what makes the “% decrement criteria” more successful at giving rise to the effect sizes. The follow-up analysis will be run using the subset of studies that used one variant of the “% decrement criteria”. Stimulus modality, presentation mode and identical stimulus will be modeled as nuisance variables. Additional variables included in the model will be 1) “% decrement N baseline trials”, 2) “% decrement N criterion trials”, 3) “% decrement percentage”, 4) “maximum N habituation trials” 5) “fixed vs. sliding window”. Each of the variables is hypothesized to positively correlate with the effect size and therefore will be tested with a one-sided test at the $\alpha=0.01$ level. The frequentist analysis will be carried out in the latest version of JASP (JASP Team, 2021).

As a robustness analysis, a fixed effects meta-analysis, random effects meta-analysis, and another meta-regression will be performed in the Bayesian framework. A Bayesian analysis offers two main advantages here. First, the predictive performance of each model can be assessed, providing direct comparison between the fixed effects null model (effect size is zero across all studies), fixed effects alternative model (effect size is positive and fixed across studies), random effects null model (the average effect size is zero but varies from study to study), random effects alternative model (the average effect size is positive but varies across studies), and the meta-regression (explaining variability in the effect sizes as a function of the model predictors). Thus, the evidence in favor of the null model can be computed, which is

otherwise impossible using the frequentist method. Second, a Bayesian meta-regression can be formulated to accommodate partially missing data per study. The primary analysis using the frequentist method to test the effect of individual characteristics of the decrement criteria requires to limit the data to the subset of studies using those criteria, therefore splitting the analysis in two steps. In the Bayesian analysis, those steps can be performed simultaneously within one model that also includes the variables for which a subset of the studies have missing data. For fitting the fixed and random effects meta-analysis, the `metaBMA` package in R will be used (Heck et al., 2019). For fitting the meta-regression model, a custom-coded Stan model will be used (Harrer, Cuijpers, Furukawa, & Ebert, 2021; Carpenter, et al., 2017). Models will be compared using the bridge sampling technique using the `bridgesampling` package (Gronau et al., 2020).

Additional Analyses

The primary analysis will be based on the standardized difference scores effect size across within-subject studies. Previous articles have warned against the use of this standardized effect size calculation for meta-analytic purposes (Dunlap, et al., 1996). The difficulty with standardized difference scores is that it depends heavily on the correlation between the novel and familiar stimuli. A correlation higher than 0.5 results in larger effect size (Dunlap, et al., 1996, Moris & DeShon, 2002) than that of the traditional between-subjects effect size (e.g., Cohen's d). Further, conducting a meta-analysis of the within-subject effect size requires the assumption that the correlation between novel and familiar stimuli is equal between all studies (Moris & DeShon, 2002). If that is not the case, one cannot interpret whether different effect sizes are due to the varying difference between the novel and familiar trials, or due to differences between their correlation. Similarly, an effect of a predictor in a meta-regression is difficult to interpret

without this assumption; for example, an increase of the effect size with increasing age might mean that the correlation between novel and familiar stimuli increases with age, rather than that the difference between novel and familiar stimuli increases.

However, it would be difficult to convert the standardized difference scores effect size into the classical Cohen's d or Hedges' g effect size, as that would either require studies reporting the means and standard deviations for novel and familiar stimuli, or the observed correlation between novel and familiar stimuli. The number of studies that do report these statistics will likely be very low.

Due to these difficulties, there will be a separate robustness meta-analysis that uses the Hedges' g effect size as the effect size of interest, from the group of studies that reported a between-subject comparison of novel and familiar stimuli, or those studies that reported a within-subject comparison, but did report the additional statistics required to calculate the between-subject effect size. The robustness analysis will be used to assess whether the conclusions from the primary meta-analysis hold with a different choice for the effect size.

Because there will be missing data in the data set (see section "Dealing with Missing Information"), we will also provide exploratory analyses investigating whether reporting practices of habituation experiments improved over time.

The analysis of habituation attrition rates is ambiguous because it is not clear what level of attrition is needed to yield a valid sample of habituated participants at the post-habitation phase. A possible way to clarify this effect is to analyze the habituation attrition and novelty effect sizes in a joint meta-analytic model. In this model, habituation design factors can be used as predictors of both habituation attrition and the effect sizes at the same time. Further, a

correlation between the two dependent variables will be estimated, which will suggest whether higher attrition rates correlate with higher effect sizes (Oakes, 2010).

Dealing with Missing Information

In descriptive analyses, the number of missing data entries for each variable of interest will be reported. In statistical analyses, only complete data (subject to the particular analysis) will be used for the main analyses. That is, we will use listwise deletion of rows in the data set based on only the variables that are entered into the specific analysis. Robustness analyses will be carried out by 1) coding missing information of categorical predictors as their own category, and by imputing the data using the `mice` package (van Buuren & Groothuis-Oudshoorn, 2011).

Results

To be added after data collection.

Discussion

To be added after data collection.

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Tables

Table 1

Descriptive Variables.

Variable name	Possible values (data validation)	Description
Study descriptors		
Experiment number	An integer with a maximum of 2 digits	The number that indexes the experiment reported in the article; “1” if only one study is reported in the paper.
Participant group index	An integer with a maximum of 2 digits	The number that indexes the experimental group.
<i>Sample descriptives</i>		
Original sample N	NA or an integer with a maximum of 4 digits	Sample size before dropouts.
Original sample female	NA or an integer with a maximum of 4 digits	Sample size of female participants before dropouts.
Average age	NA or an integer with a maximum of 2 digits	Mean [or median] age in weeks, rounded down (floored). E.g., if 42.8 weeks, enter 42.
Age range		Age range in weeks.
Community sampling	Yes, No	Were there efforts to recruit infants in a representative way (e.g., by diversifying SES background, race, etc. - unless otherwise specified, the answer is no)?
N dropout total	NA or an integer with a maximum of 4 digits	Number of infants who dropped out from the original sample.
N dropout "fussiness/crying"	NA or an integer with a maximum of 4 digits	N infants who dropped out due to fussiness/crying.
N dropout "other"	NA or an integer with a maximum of 4 digits	N infants who dropped out for "other" reasons.

N dropout “habituation failed”	NA or an integer with a maximum of 3 digits	How many infants were excluded from the analysis for not reaching a habituation criterion?
<i>Stimulus presentation & characteristics</i>		
Presentation mode	Live, Semi-automatic, Automatic, Other, NA	The materials/technology used for stimulus presentation: live = human operating physical object (e.g., puppets), semi-automatic = script presents the stimulus but experimenter controls onset times of stimuli, automatic = fully automated script.
Stimulus modality	Visual static, Visual dynamic, Auditory, Audio-visual, Other, NA	Modality of the stimuli: visual static = images, visual dynamic = video (without sound), auditory = sounds, music, audio-visual = any combination of images/video/presentation + sounds, other = any other modality.
Presence visual stimulus visualisation	Yes, No	Whether the paper provides some sort of visualisation of the visual stimuli used in the study.
<i>Looking time detection</i>		
Looking time detection method	Manual, Automatic (eye-tracking), Other, NA	How is looking time measured?
Blind coding	Yes, No/NA	Was blinding of the coders towards any aspect of the experimental procedure mentioned at all?
Coding reliability %	NA or an integer with a maximum of 3 digits	If more than one coder, what was the coding reliability (percentage)?
Coding method	Online-manual, Offline-manual, Eye-tracking, Other, NA	What method was used to calculate the final looking times for the analysis?
<i>Habituation experiments</i>		
Post-habituation phase	Yes, No	Is there a post-habituation phase in the experiment (i.e., a test phase)?

Table 2

Meta-Analysis and Analyses of Attrition Rates: Dependent and Independent Variables.

Variable name	Possible values (validation)	Description
<i>Independent variables: Habituation design</i>		
Initial sum looking time (in seconds)	NA or an integer with a maximum of 5 digits	The minimum looking time before the habituation criterion can be applied (if no threshold used, report "0").
Initial mandatory trials	NA or an integer with a maximum of 2 digits	The number of habituation trials that were presented mandatorily at the habituation phase, regardless whether the infant had reached the habituation criterion or not (if no threshold was used, report "0").
Max trials	NA, Infinite, or an integer with a maximum of 3 digits	Maximum number of trials before moving to the post-habituation phase (even if the infant has not reached the habituation criterion). If no maximum number of trials was used, report "Inf".
Stopping rule	% decrement from initial,% decrement from max,% decrement from recent, fixed N trials, fixed looking time, other	The criterion used to judge whether the infant habituated.
% decrement N baseline trials	NA or an integer with a maximum of 2 digits	If "% decrement" applied, the number trials that are considered in the stopping criterion as the baseline.
% decrement N criterion trials	NA or an integer with a maximum of 2 digits	If "% decrement" applied, the number trials that are considered in the stopping criterion as the criterion.
% decrement percentage decline	NA or an integer with a maximum of 2 digits	If "% decrement" applied, the percentage decline that is considered in the stopping criterion.
Fixed looking time criterion	NA or an integer with a maximum of 6 digits	If the stopping rule is "fixed looking time", how much looking time (in seconds) did the infant need to accumulate in order to be

		considered habituated?
Min look duration per trial	NA or an integer with a maximum of 3 digits	The minimum look duration (in seconds) for the trial to be considered valid.
End trial	NA or an integer with a maximum of 3 digits	The number of seconds that the gaze must be away to end a habituation trial.
Mean N habituation trials	NA or a numeric value	The mean number of habituation trials presented before the infant reached the habituation criterion.
<i>Independent variables: Post-habituation design</i>		
N novel trials	NA or an integer with a maximum of 2 digits	The number of novel trials presented after the habituation phase.
N familiar trials	NA or an integer with a maximum of 2 digits	The number of familiar trials presented after the habituation phase.
Sum novel & familiar trials	NA or an integer with a maximum of 2 digits	The number of test trials (novel or familiar) presented in the post-habituation phase.
Test trial ordering	Quasi-random, Alternation (ABAB), Blocked (AABB), Simultaneous, Other, NA	By which rule are the trials in the post-habituation phase presented? Note that a counterbalanced design is included in quasi-random.
Novel-Familiar trial first	Novel, Familiar, Random, Counterbalanced, Simultaneous, Other, NA	Was a novel or a familiar stimulus presented first in the post-habituation phase?
Hypothesis Novel vs Familiar	Novelty, Familiarity, Difference, Null, Not specified	In which direction did the authors expect the looking time towards the novel versus the familiar stimuli to differ?
Design Novel vs Familiar	Between, Within, NA	Is the experimental design within subject or between subjects? Code “Within” when the infants saw both the novel and familiar trials. Code “Between” if two or more subsamples of the infants were habituated to mutually exclusive experimental conditions.
Test Novel vs	Between, Within, NA	Is the statistical test of the main effect (novel

Familiar		vs familiar) within subject or between subjects? In some cases, the statistical test may differ from the experimental design.
Identical stimulus	True/False	Is the "old" stimulus shown during the post-habituation phase identical to the stimulus shown during the habituation phase? False indicates that the stimulus is of the same type or category, but not identical (if stimulus in the habituation was not constant itself, answer is False).
<i>Dependent variables: Presence & Magnitude of the post-habituation effect</i>		
Mean familiar	NA or a numeric value	Mean of the looking times to familiar trials.
SD familiar	NA or a numeric value	Standard deviation of the looking times to familiar trials.
Mean novel	NA or a numeric value	Mean of the looking times to novel trials.
SD novel	NA or a numeric value	Standard deviation of the looking times to novel trials.
T-test statistic	NA or a numeric value	If t-test used to assess the effect: The t-statistic of the t-test.
T-test df	NA or a numeric value	If t-test used to assess the effect: Degrees of freedom of the t-test.
F-test statistic	NA or a numeric value	If F-test used to assess the effect: The F statistic.
F-test df 1	NA or a numeric value	If F-test used to assess the effect: The first degree of freedom.
F-test df 2	NA or a numeric value	If F-test used to assess the effect: The second degree of freedom.
Other test		A copy of any other test of the novelty versus familiarity difference effect (e.g., Wilcoxon Test).
Cohen's d		The value of the Cohen's d effect size as reported in the original study.
(Partial) Eta Squared		The value of the (Partial) Eta Squared effect size as reported in the original study.

<i>Dependent variables: Experimental attrition</i>		
<i>N dropout total</i>	NA or an integer with a maximum of 2 digits	The number of infants who dropped out from the original sample.
<i>N dropout “habituation failed”</i>	NA or an integer with a maximum of 3 digits	How many infants were excluded from the analysis for not reaching a habituation criterion?

Appendix A

Overview of Analysis Plan per Research Question

Question	Hypothesis	Analysis plan	Interpretation given different outcomes
Descriptive analysis			
Which experimental design and reporting practices exist in the reviewed literature and how frequently are they applied?	Not Applicable.	Frequency distributions (descriptives & plots).	No fixed decision criteria; interpretation purely of descriptive nature.
What is the observed data quality among the habituation studies included in the systematic review and the meta-analysis (pooled)?	Reports show variability on the overall experimental attrition rate.	Descriptives on dropout rates (overall and due to fussiness versus other causes lumped together).	No fixed decision criteria; interpretation purely of descriptive nature.
	Reports show variability on the attrition rate from the habituation to the post-habituation phase.	Descriptives on the attrition due to a failed habituation phase.	No fixed decision criteria; interpretation purely of descriptive nature.
Analyses of Attrition Rates			
Which experimental design factors influence attrition among the habituation studies included in the systematic review?	The null hypothesis for each predictor specifies that the design choice does not affect the attrition rate. The alternative hypothesis	A binomial regression ¹ Predicting: 1) the number of drop-outs out of the whole sample	Coefficients for each predictor will be assessed at the 0.01 significance level. Bayesian analysis will express the overall level of evidence

¹ A Bayesian binomial regression with the same predictors will be used as a robustness check.

² Bayesian model averaging of fixed and random effects used as a robustness check.

³ A Bayesian meta-regression analysis will be used as a robustness check.

	specifies that the design choice is related to the attrition rate.	<p>2) the number of drop-outs due to failed habituation phase</p> <p>Predictors:</p> <ol style="list-style-type: none"> 1. Degree of automation: <ol style="list-style-type: none"> 1.1. Presentation mode 1.2. Looking time detection method 2. Other: <ol style="list-style-type: none"> 2.1. Stopping rule 2.2. The maximum number of habituation trials 2.3. Stimulus modality 2.4. Average age 	present in the data.
Meta-analysis			
What is the average size of the novelty effect during the post-habituation phase?	The null hypothesis specifies that the average novelty effect is zero. The alternative hypothesis specifies that the average novelty effect is larger than zero.	Frequentist fixed effects and random effects meta-analysis ² .	<ol style="list-style-type: none"> 1) In case the omnibus test for heterogeneity is not significant at the 0.01 alpha level, the estimate and 95% CI of the fixed effect meta-analysis is used. 2) In case the omnibus test for heterogeneity is significant at the 0.01 alpha level, the 95% CI for the average effect

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			<p>size from the random effect meta-analysis is used.</p> <p>3) Bayesian model averaging will provide the average novelty effect estimate, weighted by the posterior probability of the fixed and random effects meta-analyses, as well as the null models that assume that the average effect is zero.</p>
How are detection criteria related to the strength of the novelty effect?	<p>1) Null hypothesis specifies that there is no difference in the novelty effect between the Fixed N number of trials design and the other three % decrement criteria. The alternative hypothesis specifies that at least one of the decrement criteria differs.</p> <p>2) Among the % decrement criteria, is there an effect of the number of habituation</p>	<p>Meta-regression³ in two steps:</p> <p>1) Regressing the effect size on the categorical variable “Stopping rule” and “Age”</p> <p>2) Regressing the effect size for studies that used % decrement criteria to detect habituation on: The number of criterion and baseline trials, % of decrement, the maximum number of trials, fixed vs sliding window</p> <p>Nuisance predictors: 1) stimulus</p>	<p>1) Significant coefficients (at 0.01 alpha level) for the dummy variables will be used to reject the null hypothesis that the % decrement criteria differ from the fixed N of trials designs.</p> <p>2) Significant coefficients for the predictors will be interpreted to reject the null hypothesis that the design choices in the % decrement criteria do not matter</p>

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	trials, type of the % decrement criterion, and whether a fixed vs sliding window was used	modality (dummy coded), 2) presentation mode (dummy coded), and 3) identical stimulus will be included in the model.	3) Bayesian analysis will provide the evidence in the data for the alternative explanations.
How is age related to the strength of the novelty effect?	The null hypothesis specifies that age is unrelated to the strength of the novelty effect. The alternative hypothesis specifies that there is a positive effect of age on the novelty effect.	Meta-regression regressing the effect size on the categorical variable “Stopping rule” and “Age” Nuisance predictors: 1) stimulus modality (dummy coded), 2) presentation mode (dummy coded), and 3) identical stimulus will be included in the model.	Result of the one-sided test of the coefficient of age (expecting positive effect) will be used for interpretation.

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² Bayesian model averaging of fixed and random effects used as a robustness check.

³ A Bayesian meta-regression analysis will be used as a robustness check.

Appendix B

Search Strategy & Syntax

The searches below yielded the following results on May 21, 2020: PsycINFO (1.310 references), and Web of Science (2.548 references). The total number of references was 3.858.

APA PsycINFO (Ovid, 1806 to May Week 2 2020)

1. habituation/ OR familiarity/ OR (discrimination OR habituation OR familiarization OR dishabituation OR post-habituation OR novelty preference OR familiarity preference OR visual paired comparison).ti,ab,id,tm.
2. (neonatal birth 1 mo OR infancy 2 23 mo).ag. OR neonatal development/ OR infant development/ OR (newborn* OR new-born OR infan* OR baby* OR babies).ti,ab,id.
3. Visual Discrimination/ OR (visual inspection OR visual discrimination OR dwell* time OR gaze duration OR looking time OR look* duration OR point-light display* OR head turn* OR eye track* OR eye movement* OR visual preference* OR visual cue* OR visual pair* OR watched).ti,ab,id,tm.
4. (stimuli or paradigm or task* or experiment* or random* or control condit* or control group* OR procedur* OR habituation phase OR dishabituation phase).ti,ab,id.
5. 1 AND 2 AND (3 OR 4)
6. Limit to 2000-..
7. Limit to peer review

Key concepts: 1) habituation, 2) infants, 3) visual behavioral responses, 4) study type

Key: / = subject heading, ti = title, ab = abstract, id = key concepts (other keywords added by PsycINFO indexers to supplement the subject headings), tm = tests and measures

Web of Science Core Collection (Web of Science, 1975 to 2020)

1. TS=("discrimination" OR "habituation" OR "familiarization" OR "dishabituation" OR "post-habituation" OR "novelty preference" OR "familiarity preference" OR "visual paired comparison")
2. TS=("newborn*" OR "new-born" OR "infan*" OR "baby*" OR "babies")
3. TS=("visual inspection" OR "visual discrimination" OR "dwell* time" OR "gaze duration" OR "looking time" OR "look* duration" OR "point-light display*" OR "head turn*" OR "eye track*" OR "eye movement*" OR "visual preference*" OR "visual cue*" OR "visual pair*" OR "watched")
4. TS=("stimuli" OR "paradigm" OR "task*" OR "experiment*" OR "random*" OR "control condit*" OR "control group*" OR "procedur*" OR "habituation phase" OR "dishabituation phase")
5. 1 AND 2 AND (3 OR 4)
6. Limit to 2000-..

Key concepts: 1) habituation, 2) infants, 3) visual behavioral responses, 4) study type

Key: TS = topic, which includes title, abstract, author keywords and Web of Science

Keywords Plus

Appendix C

Overview of the Project Timeline

RR Status	Task	Relative timeline	Desired deadline
Submitted	Contact potential collaborators, establish communication channels, receive feedback from collaborators	2 months	31 December 2021
	Polish coding manual and example articles	2 months	31 January 2022
	Adjust coding scheme based on reviews and feedback	2 months	31 March 2022
	Rater training	5 months (concurrently with the first three stages)	31 March 2022
Accepted in principle	Data collection	9 months	31 December 2022
	Analysis of inter-rater disagreement, resolving remaining disagreement	1 month	31 January 2023
	Descriptive analyses and systematic review analyses	1 month	28 February 2023
	Meta-analysis	2 months	31 April 2023
	Exploratory analyses	1 month	31 May 2023
	Write up results and discussion, final report submission	3 months	31 August 2023