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How Is Calendar Calculation in Autism Possible? A Language Model

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Detailed case studies of individuals with brain injuries have long provided valuable insights into how cognitive functions are organized. Similarly, the study of individuals with highly idiosyncratic cognitive abilities can shed light on the outer limits of human cognition. One such phenomenon is calendar calculation (CC), the ability to identify the day of the week that corresponds to a given date or the dates that match a particular calendar configuration. CC is the most commonly reported “special ability” in autism and is unique in its accuracy and speed, often surpassing experienced mathematicians. Recent findings suggest that a significant proportion of autistic children with oral language delays first acquire and prefer the written code, which may help pave the way for oral language acquisition. This atypical pathway for language acquisition invites a rethinking of the mechanisms underlying CC. In this article, we propose an integrative model in which the development and mastery of CC in autism are driven by the orientation of the innate linguistic cognitive resources toward an equivalent complex symbolic system. This model offers a novel perspective on the language trajectories observed in autism, their role in facilitating expertise in nonsocial complex material, and the broader flexibility of human language-based abilities.

Keywords: autism, savant syndrome, calendar calculation, development, language

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This article is based on the results of a registered systematic review (PROSPERO: CRD42021254855). The clinical, cognitive, developmental, and behavioral correlates; the comprehensive empirical evidence on calendar calculation; and the brain imaging results during calendar calculation tasks available in the literature are reported in a companion article. The theoretical model presented in the present article is based on an exhaustive survey of the models proposed in the literature and the data reported in the systematic review. Some of the findings in this article were presented in a poster session at the International Society for Autism Research annual conference in Melbourne, Australia, in May 2024. The content of the present article does not overlap with that of the systematic review, has not been published, and is not under consideration for publication elsewhere.

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Unique and rare case studies have elucidated some fundamental mechanisms of the human brain but have also led to specific advances in the comprehension of the cognitive particularities of certain clinical populations. For example, the case of Phineas Gage (Harlow, 1848) demonstrated the essential role of the frontal lobe in behavior and personality. Impulsive behavior and social and planning difficulties were observed following his frontal lobe trauma, associating the region with control functions. Another case, H.M. (Milner, 1962), provided deeper insights into the importance of the hippocampus in the formation of new memories, allowing the distinction between different types of memory and the specification of their neural support. Following the bilateral removal of his hippocampus, H.M. suffered from severe anterograde amnesia, preventing him from encoding new information while preserving old memories and procedural learning. In autism, the empirical study of graphic constructions by E.C. (Motttron & Belleville, 1993, 1995), an autistic savant draughtsman, has led to an in-depth reevaluation of the role of perception in autistic cognitive and behavioral phenotypes. E.C.'s case provided critical insights into enhanced local processing bias and reduction of top-down influences. These results have been replicated in nonsavant populations (e.g., high prevalence of perceptual strengths in the autistic population, Meilleur et al., 2015; reduction of top-down influences in visuospatial tasks, Caron et al., 2006; and have been instrumental in the more recent Bayesian models of autistic cognition, Palmer et al., 2017).

The savant syndrome refers to the presence of at least one special ability in a circumscribed domain that contrasts with an individual's general cognitive and/or adaptive functioning (Heaton & Wallace, 2004; Miller, 1999). Special abilities can encompass recurrent skills in a limited series of fields such as drawing, music, mathematics, visuospatial abilities, or calendar calculation (CC; Miller, 1999). The association of savant syndrome with autism is unquestioned (Happé, 2018; Howlin, 2012; Motttron et al., 2013; Muniz et al., 2025; Park, 2023; Rudziński et al., 2024). Its reported prevalence varies widely from 39/137 (28.5%; Howlin et al., 2009) to 9.8% of autistic individuals (Rimland, 1978) to 1.4/1,000 of individuals with intellectual disability (Saloviita et al., 2000) and is highly dependent on definitions, sources of information, reference populations, and trends of autism prevalence (Waterhouse, 2013).

Among savant abilities, CC is one of the most common and documented (e.g., 62 out of 152 savants; Miller, 1999), as well as one of the most accessible to empirical study (Howlin et al., 2009; Saloviita et al., 2000). CC involves the ability to provide calendar-related information, typically day–date correspondence (e.g., what day was June 23, 1934) or “reverse” questions (e.g., what are the years of this century in which March begins with a Tuesday) within seconds. This ability can be acquired by some mathematically gifted nonautistic individuals through the explicit application of complex algorithms (Hermelin, 2001). However, some autistic savants exhibit a precocious, unexpected, self-taught, extremely fast, and accurate proficiency in CC. The developmental trajectory, underlying cognitive mechanisms, and reasons for its predominant prevalence in autistic individuals remain largely unexplained. Models based on a single cognitive atypicality, overfunctioning, or autism-related mechanism do not take into account all available data and overlook the *generativity* of CC, the capacity to provide calendar information they have never been exposed to. Models that explore the association of various cognitive atypicalities found in autism often

overlook the importance of the sequence and chronology in the acquisition of these abilities.

Recent findings from a large-scale empirical study show that early interest in written codes is one of the main distinguishing behaviors associated with autism in preschool-aged children (Stanley et al., 2025). Systematic reviews demonstrate that some prototypical autistic children can learn language in a noninteractive manner (Beccaria et al., 2025; Dumont et al., 2024; Kissine et al., 2023), giving great importance to written material in language acquisition (Ostrolenk et al., 2023, 2024). Recent brain imaging results support the inversion in neurotypical brain network hierarchies favoring transmodal functions to the benefit of perception (Bernhardt et al., 2025), as predicted by the Enhanced Perceptual Model of Autism (Motttron, Dawson, et al., 2006). Based on these previously overlooked data, the bifurcation model of autism (Motttron & Gagnon, 2023) emphasizes a gradual, family-bound reduction of social bias (the automatic preferential processing of information related to conspecifics) in the early years of life. Accordingly, children would engage with perceptual and structural content without preferential attraction to social content, thus opening up the possibility of materials other than oral language to be analyzed as such. Despite its rarity, similarly to the previously stated case studies, the successful modeling of CC is an acid test for major theories of cognitive and developmental models of autism. Beyond autism, advances at this level contribute to a broader understanding of the various forms human language abilities can take and how they relate to exposure and social input.

Method

A registered (PROSPERO: CRD42021254855) systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Page et al., 2021). A literature search on PubMed, Web of Science, APA PsycInfo, ProQuest Dissertations and Theses, and Linguistics and Language Behavior Abstracts with the terms “Calendar calculation(s),” “Calendar calculator(s),” “Calendar computation,” “Calendrical calculators,” “Calendar calculating,” “Calendrical calculation,” “Calendrical savants,” and “Calendar savant” generated 70 articles (1920–2023), involving 98 different individuals with CC abilities (88M). To be included, the article had to be in English or French, document at least one participant capable of identifying the day of the week of a specific date with a success rate higher than chance, have original data, report individual results, and not identify a calendar calculator through a self-reported questionnaire. Their clinical, cognitive, developmental, and behavioral correlates, as well as the exhaustive empirical findings on CC and the overall available brain imaging results during CC tasks, are reported and available in a companion article.

Based on this systematic review, the present article evaluates past and current models that attempt to explain how CC is made possible by the deficit or amplification of a single cognitive mechanism or by the combination of several related mechanisms, as well as the articles that integrate cognitive atypicalities found in CC in the context of its occurrence in autism. To do so, all articles included in the systematic review were subjected to a thematic analysis to classify the models proposed by each article. JD and a research assistant independently extracted models and justifications for all articles. Common patterns were then grouped together by model classification, and the plausibility of each model is discussed in relation to available empirical

data. To conclude, a new model is proposed that accounts for the acquisition, development, and cognitive functioning of CC.

How Is CC Possible?

The first set of explanations for *how* CC is possible involves the deficit or overfunctioning of a particular ability: (a) pattern detection, (b) arithmetic, (c) the different components of memory (episodic, semantic, implicit, visual), (d) synesthesia, and (e) the “anchoring” model, which involves the atypical interaction of several of these functions.

Pattern Detection

The calendar is a complex structure composed of words and numbers arranged in predictable and regular patterns (see Appendix “Calendar Theory”). Its redundancy and constraints can be unfolded in a set of rules. The “pattern” model for CC assumes that exposure to the calendar structure allows the detection of regularities that are then internalized as rules (Horwitz et al., 1969), without initially being explicitly worded. The use of regularities presupposes their implicit detection by exposure (Heavey, 1996; Heavey et al., 2012), since explicit learning is excluded (Jensen, 1990; Young & Nettelbeck, 1994).

Support for the use of pattern detection to perform CC was reported by 14 calculators (Cowan & Carney, 2006; Cowan et al., 2004; Dorman, 1991; Ho et al., 1991; Minati & Sigala, 2013; Parker et al., 2006; Shields-Wolfe & Gallagher, 1992), emphasizing that a certain date “is the same as” another date or group of dates in the calendar or providing a series of identical structures separated by the 28-year rule (Ho et al., 1991). Systematic errors (Barnejee, 1975; Benoit et al., 1965; Courchesne et al., 2020; Cowan & Carney, 2006; Cowan et al., 2004; Ho et al., 1991; Howe & Smith, 1988; Iavarone et al., 2007; Patti, 1994) also indicate the overgeneralized use of calendar regularities, failing to take account of certain exceptions in them.

Arithmetic

Nonautistic mathematical experts report learning and explicitly using complex formulas to answer CC questions (Cowan & Carney, 2006; Dubischar-Krivec et al., 2009, 2014; Minati & Sigala, 2013; Pesenti et al., 1999, 2001). Algorithm use involves explicit learning, a step-by-step procedure, and explicit application when solving a CC question. The algorithm model for CC hypothesizes that the autistic calculators solve CC problems using the same algorithms as nonautistic calculators (e.g., Carroll, 1887; Cohn, 2007; Mayr, 1959) or by an algorithmic-type process of their own.

Arguments against the use of algorithms by autistic calculators include the lack of teaching or evidence of access to these algorithms, especially in the preinternet era, and the absence of insight from the calculators themselves when asked how they arrived at their answers. Compared to a mathematician who can explicitly name and explain the algorithm he was using, the autistic participants were unable to report any information about it (Cowan & Carney, 2006). A lack of introspective capacity (defined here as the participants’ ability to describe the steps that led them to learn CC or the processes they use to perform it) regarding their ability was reported for 21 calculators with at least one feature of autism (Barnejee, 1975;

Benoit et al., 1965; Byrd, 1920; Dubischar-Krivec et al., 2009; Heavey, 1996; Heuyer & Badonnel, 1928; Horwitz et al., 1965, 1969; Howe & Smith, 1988; Hurst & Mulhall, 1988; Nurcombe & Parker, 1964; Olson et al., 2010; Palo & Kivalo, 1977; Parker et al., 2006; Rosen, 1981; Scheerer et al., 1945; Smith & Howe, 1985; Wallace, 2006; Wallace et al., 2009). Also, the absence of error patterns reported in some cases (Mottron, Lemmens, et al., 2006; Rosen, 1981) does not support the use of algorithmic procedures, which would be expected to produce nonrandom, systematic errors. Moreover, extremely short response time (RT) is not compatible with the use of multiple steps in an algorithm (Benoit et al., 1965; Dubischar-Krivec et al., 2009; Horwitz et al., 1969; Peru, 2023).

Nor is the ability to answer reverse questions (Abhyankar et al., 1981; Barnejee, 1975; Benoit et al., 1965; Bouvet et al., 2014; Byrd, 1920; Cowan & Carney, 2006; Cowan et al., 2003; Fauville, 1936; Heavey, 1996; Hermelin & O’Connor, 1986; Heuyer & Badonnel, 1928; Heuyer et al., 1946; Ho et al., 1991; Horwitz et al., 1965, 1969; Howe & Smith, 1988; Jensen, 1990; Lafora, 1935; Mottron, Lemmens, et al., 2006; O’Connor et al., 2000; O’Connor & Hermelin, 1984; Olson et al., 2010; Palo & Kivalo, 1977; Patti, 1994; Patti & Lupinetti, 1993; Scheerer et al., 1945; Shields-Wolfe & Gallagher, 1992; Smith & Howe, 1985; Thioux et al., 2006; Wallace, 2006; Wallace et al., 2009; Young, 1995; Young & Nettelbeck, 1994) explained by these algorithms. If an algorithm was used, RT would not increase with distance from the present, which seems to be the case in a fraction of autistic calendar calculators (Courchesne et al., 2020; Cowan & Carney, 2006; Cowan et al., 2003; De Marco et al., 2016; Ho et al., 1991; Howe & Smith, 1988; Iavarone et al., 2007; Peru, 2023; Pring & Hermelin, 2002; Rosen, 1981; Smith & Howe, 1985; Thioux et al., 2006). As for the use of consecutive “simple” arithmetic operations, their number should depend on the distance from the present date. This hypothesis is supported by some empirical results. For example, three calculators (Cowan & Carney, 2006; Cowan et al., 2003; Ho et al., 1991) who had written the calculation steps before answering future questions took longer for further dates by writing down more calculation steps. Also, the longer RT for more distant dates could be indicative of a greater number of arithmetic steps (Cowan & Frith, 2009; De Marco et al., 2016; Dorman, 1991; Dubischar-Krivec et al., 2009; Iavarone et al., 2007; Minati & Sigala, 2013; O’Connor & Hermelin, 1984). However, the possible use of arithmetic is unlikely in some calculators with limited verbal, intellectual, arithmetic, working memory, and long-term memory abilities (Dubischar-Krivec et al., 2009; Hill, 1975; Horwitz et al., 1965, 1969; Olson et al., 2010; Roberts, 1945). In addition, imaging data support the use of some kind of arithmetic operation by the activation of the parietal region but do not orient specifically toward algorithms (Cowan & Frith, 2009; Minati & Sigala, 2013). In sum, the use of algorithms cannot be formally excluded for some calculators, mostly nonautistics, but cannot explain the large part of them. As for the use of simple arithmetic, it can be occasionally used with another strategy but cannot explain reverse questions and extremely short RT in some of them.

Memory

Rather than the effect of a particular memory system, the involvement of memory in CC has often been presented as “rote memory” to indicate an effect of practice, recalled verbatim (Hermelin & O’Connor, 1986; Hill, 1975; Ho et al., 1991; Horwitz et al., 1965;

Howe & Smith, 1988) without further information on the memory system used (Hurst & Mulhall, 1988; Parker et al., 2006).

Its use as an exclusive explanation for CC is compatible with very short RT (Peru, 2023; Rosen, 1981; Rubin & Monaghan, 1965); parahippocampal and middle temporal gyri activation (Minati & Sigala, 2013), which is associated with extensive practice and long-term memory; and hippocampal activation (Boddaert et al., 2005) involved in memory processing. Some participants also self-reported using only the memorization of dates, but they all had a small, limited range (Byrd, 1920; Heuyer et al., 1946; Palo & Kivalo, 1977; Patti, 1994). However, the extremely wide range of certain calculators is inconsistent with low memory as measured by standardized tests in a proportion of calculators (Bicakci et al., 2021; Cowan et al., 2003; O'Connor et al., 2000; Puente et al., 2016; Young, 1995; Young & Nettelbeck, 1994). Also, systematic errors (Barnejee, 1975; Benoit et al., 1965; Courchesne et al., 2020; Cowan & Carney, 2006; Cowan et al., 2004; Ho et al., 1991; Howe & Smith, 1988; Iavarone et al., 2007; Patti, 1994) discarded memory as a single underlying mechanism subtending CC since these would rather result from the strict application of an erroneous rule. Explanations of CC through memorization of dates suffer from their underconceptualization and do not explain the reverse questions, the systematic errors, the extreme ranges, and, of course, answering questions on future dates.

Episodic Memory

Episodic memory refers to the encoding in long-term memory of information related to events experienced or encountered by an individual (Heavey, 1996). Memories can also be attached to the date or place where they occur. Episodic memory is involved in various ways in CC but cannot alone explain this capacity, for motives partially overlapping those against a “rote memory” hypothesis. The fact that the dates of the past are answered with fewer errors (Iavarone et al., 2007; Minati & Sigala, 2013; Olson et al., 2010), with a longer range (De Marco et al., 2016; Dubischar-Krivec et al., 2009; Hermelin & O'Connor, 1986), and subjectively more easily (Minati & Sigala, 2013) than the dates of the future could be explained by the facilitative effect of episodic memory, at least for the dates that have actually been experienced. The specific case of Easter, whose dates are determined not by calendar regularities but by lunar and solar cycles, is particularly informative in this regard. The superior performance in producing Easter dates that occurred during the calculator's lifetime, compared to those that occurred before or after, indicates the “opportunistic” use of episodic memory when calendar regularities do not provide a response (De Marco et al., 2016; Parker et al., 2006).

In CC, information of an episodic nature is produced spontaneously when calculators respond to calendar questions (Cowan et al., 2003; Howe & Smith, 1988; Nurcombe & Parker, 1964; Olson et al., 2010). Their autobiographical part includes the context of a moment in the history of an individual and their subjective experience. This information also includes the associations that are semantically linked to it (e.g., the birthday date of a celebrity or a date linked to the broadcast of a film). Those surrounding a calculator may discover the ability to recall a date with the day it corresponds to during conversations involving past events (Malhotra et al., 1973). Several calculators, when graphically recalling entire calendars, insert episodic elements or general knowledge (release of a film, birth of a celebrity, birthday of a person) that are linked to the recalled calendar (Nurcombe & Parker, 1964).

The exceptional memorization of areas of information reaching the importance of an interest that is both intense and atypical (e.g., dates of matches for a scholar in sports statistics or in filmography) can be structured by the dates of their occurrence. For 52 participants, excellent memory regarding episodic date-related information was reported (Abhyankar et al., 1981; Altshuler & Brebbia, 1968; Benoit et al., 1965; Bicakci et al., 2021; Bouvet et al., 2014; Courchesne et al., 2020; Cowan & Carney, 2006; Cowan et al., 2003, 2004; Cowan & Frith, 2009; De Marco et al., 2016; Dorman, 1991; Dubischar-Krivec et al., 2009, 2014; Fauville, 1936; Gilmore & Hayes, 1996; Goodman, 1972; Heavey, 1996; Heavey et al., 2012; Hermelin & O'Connor, 1986; Heuyer & Badonnel, 1928; Heuyer et al., 1946; Hill, 1975; Horwitz et al., 1965, 1969; Howe & Smith, 1988; Kennedy & Squire, 2007; Lafora, 1935; Malhotra et al., 1973; Malkoff, 1982; Minati & Sigala, 2013; Mottron, Lemmens, et al., 2006; Nelson & Pribor, 1993; Nurcombe & Parker, 1964; O'Connor et al., 2000; O'Connor & Hermelin, 1984; Olson et al., 2010; Parker et al., 2006; Patti, 1994; Pring & Hermelin, 2002; Rosen, 1981; Scheerer et al., 1945; Shields-Wolfe & Gallagher, 1992; Smith & Howe, 1985; Thioux et al., 2006; Wallace, 2006; Wallace et al., 2009; Young, 1995; Young & Nettelbeck, 1994). Although it involves dates, the memorized material is sometimes of an episodic nature (e.g., menu eaten on such a day) or semantic (filmography of an actor). The information in episodic memory seems to function in a bidirectional manner, with the date acting as a recall cue for the associated content, and vice versa.

Implicit Memory

The property of calendar mechanisms being not consciously or verbally accessible points toward implicit learning. Implicit memory refers to the functional isolation of one of the components of long-term memory, which is acquired and utilized unconsciously. It is linked to priming (as discussed above), to procedural memory (which operates in a unidirectional manner and is therefore incompatible with the multidirectional access required for reverse questions), and to perceptual recognition mechanisms (which will be examined in relation to visual imagery and visual memory).

CC certainly involves implicit memory, since 25 calculators were not able to document their learning mode and recall mechanisms (Barnejee, 1975; Benoit et al., 1965; Byrd, 1920; Dubischar-Krivec et al., 2009; Heavey, 1996; Heuyer & Badonnel, 1928; Ho et al., 1991; Horwitz et al., 1965, 1969; Howe & Smith, 1988; Hurst & Mulhall, 1988; Malhotra et al., 1973; Moriarty et al., 1993; Nurcombe & Parker, 1964; Olson et al., 2010; Palo & Kivalo, 1977; Parker et al., 2006; Rosen, 1981; Rubin & Monaghan, 1965; Scheerer et al., 1945; Smith & Howe, 1985; Wallace, 2006; Wallace et al., 2009). The involvement of subcortical and cerebellar systems in implicit memory has been reported in a single imaging study (Fehr et al., 2011). Implicit memory encompasses a large variety of processes and domains of information, from motor to language. Involving an implicit mechanism in CC is therefore more informative about the mechanisms it excludes than about those that allow CC.

Visual Memory and Imagery

Multiple calculators display or report an interest for examining, drawing, and encoding the visual attributes of calendars (Dorman, 1991; Howe & Smith, 1988; Patti & Lupinetti, 1993; Shields-Wolfe &

Gallagher, 1992; Smith & Howe, 1985), suggesting a visual memory and/or imagery component in CC. The involvement of visual memory assumes that information would be entered, recalled, and manipulated in at least a partially analog form. This could explain a certain heterogeneity in the performance of calculators favoring visually salient parts such as the months at the beginning and end of the year (Kennedy & Squire, 2007) or those that would be scanned first (e.g., in left-to-right reading) over others. The ability to complete a partially presented calendar (Roberts, 1945) or to identify in 1 s which template it belongs to (Kennedy & Squire, 2007) goes in this direction. Conversely, the variability of access in reverse questions and the use of regularities exclude that “photographic memory” or eidetic memory (Horwitz et al., 1965) can, by itself, explain calendar operations. Retention testing of visual short-term memory by the visual digit span test and the Benton Visual Retention Test has only been the subject of one report (Hill, 1975). However, this does not exclude the possibility that mental imagery plays a role in entry or recall and therefore that the calculator “moves” into a partially analog representation of the calendar (Howe & Smith, 1988; Smith & Howe, 1985).

Also suggesting a visual imagery component in CC, autistic calculators activated the visual processing region (lingual gyrus, right superior occipital gyrus, left fusiform gyrus, and left calcarine gyrus) during calendar tasks, even if the task presentation was verbal (Dubischar-Krivec et al., 2014). Comparing CC tasks between an autistic and nonautistic mathematician revealed that the autistic participant engaged bilateral occipital and parietal cortical networks associated with visual processing and eidetic imagery during CC, specifically for past dates (Fehr et al., 2011). This hypothesis is supported by the autistic participant’s observation that past dates were more vividly linked to visual impressions and historical facts. In contrast, these regions were not activated in the mathematician participant, who reported relying on mathematical algorithms for the task. Consistently, visual mental imagery abilities in a fraction of autistic people are superior or different (Bled et al., 2024). Autistic individuals activate visual regions to a larger extent compared to nonautistic individuals for processing language and semantic information (Degré-Pelletier et al., 2024; Gaffrey et al., 2007).

While visual encoding may facilitate CC with the reduction of working memory load (Cowan & Carney, 2006) in sighted calculators, it may occasionally be substituted with other functions: A blind participant who had no contact with visual or Braille calendars exemplifies this (Rubin & Monaghan, 1965).

Synesthesia

Synesthesia is a phenomenon where the stimulation of one sense automatically triggers a perception in another sense (Simner & Hubbard, 2006; van Leeuwen et al., 2020). Within autism, synesthesia is especially frequent in savant syndrome (Bouvet et al., 2019; Hughes et al., 2017). Its prevalence is anecdotally associated with memorization of sequences of digits in a savant (Baron-Cohen et al., 2007) and, more generally, with nonsocial signs of autism (Taylor et al., 2023). Only one case study reports the use of synesthesia for CC. The calendar calculator explicitly mentioned, “I’m thinking with musical notes: C is Monday, D is Tuesday, E is Wednesday, F is Thursday, G is Friday, A is Saturday, and B is Sunday. And these seven notes are one week.” He indicated that it was easier for him to perform CC because of this association.

To test the role of synesthesia in learning CC, Hughes et al. (2019) exposed 13 individuals with sequence-space synesthesia and 22 control participants to six tutorials on calendar structure over a period of 3 weeks. Based on 40 simple questions between 2011 and 2017, individuals with synesthesia ($M = 84.23\%$, $SE = 3.87$) demonstrated superior performance in CC compared to those without ($M = 67.98\%$, $SE = 5.99$). However, the study was conducted online, with nonautistic participants, of whom 63% discontinued their participation, and is minimally informative on the actual role of synesthesia in autistic CC. More generally, the increased prevalence of synesthesia, absolute pitch, and enhanced/earlier knowledge of alphabets in autism (Mottron et al., 2013; Ostrolenk et al., 2024), all involving the mapping of series of elements (e.g., letters and colors), each occupying an analogous order in ordered sequences, is nevertheless suggestive that autism favors a broad class of atypical perception and learning of linguistic and nonlinguistic series.

Combined, “Anchoring” Models

Combined models have integrated the observation of the multiplicity of methods within and between participants and have attempted to show that the combination of two or more of the suspected “modular” mechanisms was most often used. The anchoring model is based on the combined involvement of memorizing, arithmetic, and knowledge of calendar rules. It consists of using one or more dates that are memorized as references to determine the answer through additions or subtractions while applying the calendar rules and exceptions. The use of anchoring dates (a memorized event from which, by simple addition or subtraction, the exact answer is produced) was reported for 11 participants: film release dates (Courchesne et al., 2020), using the current year (Dorman, 1991), religious dates (Fauville, 1936; Hurst & Mulhall, 1988; Rosen, 1981), and random dates (Hoffman, 1971; Horwitz et al., 1969; Lafora, 1935; Nurcombe & Parker, 1964; Scherer et al., 1945; Young & Nettelbeck, 1994).

A variation in RT across dates on which participants were questioned was also interpreted as a sign of the use of anchor dates (e.g., Cowan & Carney, 2006; Dubischar-Krivec et al., 2009; Hermelin & O’Connor, 1986; Mottron, Lemmens, et al., 2006; Patti & Lupinetti, 1993; Rosen, 1981; Thioux et al., 2006). As time increased, the question date would move further away from the anchor date, and therefore, more operations had to be calculated to find the right answer.

On the contrary, the absence of measurable variation did not discard the participant’s reliance on precise anchors (Dorman, 1991; Hill, 1975; Ho et al., 1991; Kennedy & Squire, 2007; O’Connor & Hermelin, 1992). Furthermore, anchoring with the memorization of an event cannot work for the future, is unlikely for very distant terminals in the past and exceeding the life of the calculator, requires many anchor dates to limit the additional operations necessary for a simple mental calculation, and would be difficult for calculators with lower IQs. In this kind of situation, calendar rules would be used to allow extrapolations into the future or the past.

Thioux et al. (2006) developed an anchoring model that includes dates from the past as well as those from the future, supported by in-depth analysis of Donny, an autistic calculator of limited measured intelligence, judged by the authors as the most efficient in the literature. He did 14 different tasks, all supporting

one or more components that could explain the anchoring model. However, this model does not consider the modes of ability acquisition. For some participants, it helps explain how they proceed but does not cover the question of the nature of the emergence of competence as such.

Summary on Knowledge on How CC Happens

The combination of episodic memory, anchor date, and simple arithmetic, taking benefits of calendar regularities in varying proportions, accounts for how CC is *performed* in most cases but does not explain how this knowledge is *acquired*. CC involves multiple and diverse interactions between a wide range of cognitive systems: perception, memory, language, and reasoning. Each participant uses an idiosyncratic, and perhaps opportunistic, combination of methods, which further differs depending on the question asked. Even within a participant, a list of questions on consecutive dates are not necessarily answered in the same way: Some may be memorized as anchor dates; others are calculated arithmetically from them. The degree of importance attached to either memory or arithmetic would vary from one individual to another and from one date to another depending on the dates required and their cognitive resources.

Why Does CC Happen?

Models that attempt to explain *why* CC occurs in autism make its occurrence dependent on one or more of the behavioral and cognitive characteristics attributed to autism, which in turn would explain why some autistic individuals are savants, and among them would be calendar calculators. These models include the autistic uneven cognitive and motivational profile, overexposure, the “weak central coherence” model, the “veridical mapping” model, and the “systematizing” model.

Autism Uneven Cognitive and Motivational Profile

Miller’s (1998) discrepancy-based and Treffert’s (1989) splinter-skills models explain savant syndromes in terms of the dissociation between impaired and retained skills and interests that is said to be specific to autism (Happé & Frith, 1996; Rumsey, 1992). According to this model, an autistic individual can present a heterogeneous profile of cognitive competence, with variances in performance across different domains (Happé & Frith, 1996). For example, the same person might perform exceptionally well on a number-specific memorization task while being deficient on a letter-specific memorization task. The cognitive skill required, memory, is the same, but performance varies according to the material used. Performance domains are subject to variation according to the interests of autistic individuals. Interest in a particular domain can be expected to enhance motivation, leading to increased engagement in high-frequency practice and exposure. This, in turn, can be anticipated to result in enhanced performance. However, this enhancement in performance is specific and limited in scope, pertaining exclusively to the domain of interest. Savant syndromes would be a manifestation of this dissociation, as well as the manifestation of the very high level of intrinsic motivation and self-gratification of an autistic interest. Since CC is the canonical example of these dissociations, these models are tainted by circularity.

Overexposure

Overexposure to calendars is frequently documented (e.g., Abhyankar et al., 1981; Byrd, 1920; Cowan & Carney, 2006; Cowan & Frith, 2009; Hill, 1975). Some calculators spend an enormous amount of time drawing and studying calendars (Howe & Smith, 1988; Hurst & Mulhall, 1988), have a great ability to concentrate, and are obsessed with calendars (Hill, 1975; Olson et al., 2010; Peru, 2023; Rubin & Monaghan, 1965). Capitalizing on this observation, Wallace (2006) and Spitz (1995) proposed that overexposure to calendars, facilitated by the intense and restricted interests that characterize autism, could lead to implicit learning of calendar structure. The resulting automatization of recall would thus explain the short RT (Cowan et al., 2003; Horwitz et al., 1965; Olson et al., 2010; Parker et al., 2006; Peru, 2023; Rubin & Monaghan, 1965). The overexposure hypothesis is supported by the fact that some calendar calculators explicitly attempt to improve their abilities through practice (Byrd, 1920); however, no performance difference is observed between adults and children (O’Connor & Hermelin, 1992), suggesting a saturation effect. This model predicts that overexposure to the calendar and explicit learning in any individual would allow the achievement of the same performance as calculators (Hughes et al., 2019). However, neurotypical individuals do not reach the level of autistics even after practice (Dubischar-Krivec et al., 2009). Critically, overexposure is usually observed after the ability to calculate calendars has been demonstrated and does not fully explain the origin of their ability nor their intrinsic motivation, thus highlighting the need for other explanatory factors (Young & Nettelbeck, 1994).

Weak Central Coherence Model

Hierarchical models of savant abilities (Happé & Vital, 2009) explain them in terms of a detail-focused cognitive style that is itself the result of “weak coherence.” These models are based on the strengths that autistic people generally show in processing parts of figures, especially in the block design task (Shah & Frith, 1983) and the embedded figure task (Shah & Frith, 1983). They represent the nonsocial counterpart of the “mindblindness” that dominated cognitive models of autism at the end of the 20th century. In the area of CC, Heavey et al. (1999) suggested that the detection of small regularities in day–date may initiate calendar ability. This conceptual pair has been (diversely) identified with top-down (vs. bottom-up) mechanisms, meaning (vs. surface) processing, local/featural (vs. global/configural) visual perception, exemplar-based (vs. categorization or prototype) memory, or even context-independent versus context-dependent representation.

Despite their abundant posterity, the concepts of “detail” and “coherence” have never been precisely defined outside of visuo-spatial tasks, making it difficult to falsify the models that involve them. In vision, the hypothesis of a deficit in the processing of global block patterns has been refuted (Caron et al., 2006). To apply to CC, the concept of “detail” must be taken in a very abstract sense to account for regularities such as the 28-year rule, which on the contrary requires the matching of very large sets of data. The generalization of calendar rules to the future is a form of abstraction, detached from their possible origin in nearby or lived dates, to extend to the entire calendar. Whatever way “local” is applied to CC, it imperfectly

matches calendar interest and ability. Although this model offers a valuable perspective on the relationship between top-down and bottom-up processes in autism, it also predicts deficits that do not appear in the domain of perception.

Veridical Mapping Model

The veridical mapping model (Mottron et al., 2009, 2013), a component of the enhanced perceptual functioning model (Mottron, Dawson, et al., 2006), is based on the increased prevalence in autism, particularly in savants, of stable, long-term associations between the elements constituting two ordered series of units present in the environment that share an isomorphic pattern. It assumes an implicit and preferential recognition of large structures through the perceptual detection of their redundancy (within-code isomorphism), with a neuronal stabilization of individual units combining two domains of information (between-code isomorphism). This would be the case for letter-color units in grapheme-color synesthesia, letter-letter name units in hyperlexia, and pitch-label units in absolute pitch, whose precocity and incidence are dramatically enhanced in autism. The extraction of shared “rules” would thus rely on the perceptual detection of similarities between structures and the storage of corresponding anchoring units based on a particular type of memory. The perceptual discovery of pattern redundancy would thus explain both the heightened interest in codes and the discovery of large-scale isomorphisms within codes, such as the calendar structure. The “glue” of whatever kind that binds a date and its day of the week together would be of the same kind as the “glue” that binds absolute, context-free associations such as absolute pitch.

This model excels at accounting for the detection of regularities and the units that compose them, based on a property common to both savant and nonsavant autism. It provides an economic explanation for regularity detection and anchoring. On the other hand, it struggles to explain the computational aspects of these units in CC and, more generally, how perceptual mechanisms lead to the production of new rule-obedient material. Calendar rules are not perceptual because they are linguistic structures composed of ordered letters and numbers. This explains the semantics of the ability but only partly the generativity of its syntax.

Systematizing Model

The extreme male brain theory (Baron-Cohen, 2002) proposes that within the population, two sex-dependent cognitive profiles are identified: the “systemizing” male profile and the “empathizing” female profile. The cognitive functioning in autism would be the result of hypermasculinization of the brain. This proposal resulted in the formulation of the hypersystematizing model (Baron-Cohen, 2006, 2008), which aims to explain several features of autism: sex ratio, perceptual aspects, family predispositions, social and nonsocial signs, and savant syndrome. Applied to CC, the hypersystematizing model involves the two extremes of a hierarchy of information processing, perception and reasoning. A hypersensitivity of the sensory system would be oriented toward a better processing of the details of the information. A higher setting of an evolutionarily selected human ability, systematization, would orient the individual toward the analysis and construction of structured information governed by “if p, then q” implications. The systems thus discovered could be perceptual and

static (visual patterns) or dynamic (periodic movements) or systematic associations such as calendar laws.

The model cleverly links the choice of the domain of interest (the “why” calendars are selected) and the recognition and use of their regularities (the “how” CC is performed) to strengths inherent to autism. It legitimizes a deep kinship between calendars and other domains in which scientists excel, as it justifies that we do not find special abilities in insufficiently regular domains. However, findings on the empirical bases of the extreme male brain theory, especially biological ones, remain restricted to a single research group. Sensory hypersensitivity has been empirically demonstrated only in hearing (Bonnell et al., 2010). The most convincing results in vision (Ashwin et al., 2009) were based on a methodological flaw (Bölte et al., 2012). Most of the results showing improved perception are relative to speech deficits rather than absolute (Dawson et al., 2007) or related to a reduction in global-local interference (Caron et al., 2006). They do not, or very rarely, show psychophysical superiority of the sensory system.

A New “Language” Model of CC, Explaining How It Works and Why It Happens

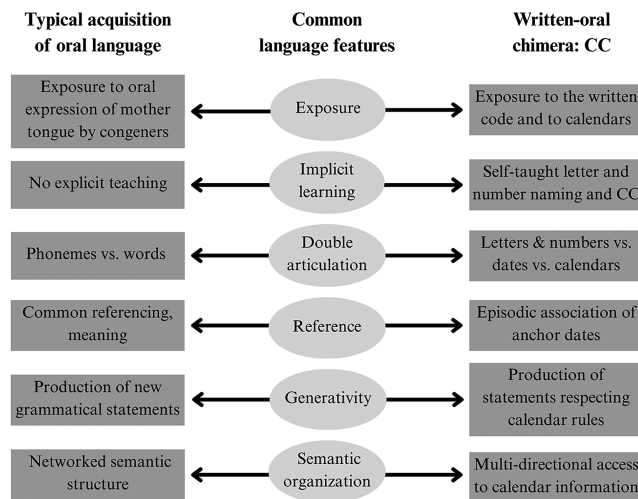
Some authors have evoked the similarity between CC and certain aspects of natural language learning and its structural components and use. The rapid and unconscious processing of calendar material could be likened to the acquisition of L1 (Jensen, 1990). The implicit knowledge of calendar rules could require the same type of cognitive ability as the implicit acquisition and use of grammatical rules (Heavey, 1996; Heavey et al., 2012; Hermelin & O'Connor, 1986; Jensen, 1990; O'Connor & Hermelin, 1984; Young & Nettelbeck, 1994). Both would result from repeated exposure to regularities, enabling the extraction of rules. We will now propose an original model based on the commonalities between natural language and calendar properties, now supported by a large series of clinical, empirical, and imaging findings regarding the atypical way in which prototypical autistic children access language. Despite being initially composed of written elements, calendar knowledge could be acquired, organized, and used in a way partially analogous to that enabling the acquisition, mastery, and use of oral language. Seven areas of similarity between oral language mastery and CC will be developed: the role of exposure, its implicit mode of acquisition, the “double articulation,” the reference to real-world objects, the syntactic generativity, the network organization, and the link with oral and written language (Figure 1).

Role of Exposure in Oral Language, Written Language, and CC Acquisition

The role and nature of exposure to oral language in the typical acquisition of L1 appear strikingly similar to the role and nature of exposure to letters and numbers, then calendars in the learning of CC, albeit through written rather than oral language. In neurotypical individuals, exposure to oral language occurs at a critical phase, anterior to the acquisition of literacy, through interaction with the rearing environment (Tomasello, 2020). Rule extraction of oral language is implicit and based on exposure rather than being explicitly taught.

Prototypical autism is dominantly characterized by delays and/or regressions in the language acquisition curve after the acquisition of

Figure 1
Shared Language Features Between the Acquisition of Oral Language and CC



Note. Six characteristics of the acquisition, mastery, and functioning of language (in the center) are shared between oral language (on the left) and the written–oral “chimera” of CC (on the right). CC = calendar calculation.

a few words (Motttron et al., 2021; Ozonoff & Iosif, 2019). Autistic children, during the period when neurotypical children learn oral language, do not direct their interest toward the oral language spoken by their parents or human voices in general. They rather show a preference for complex perceptual information available in their environment (Jacques et al., 2018). They also actively seek it once they have encountered it. Some of this researched, complex, nonsocial information relates to language in the form of an early and intense interest in *written* symbols such as letters and numbers, which is the behavior most associated with a diagnosis of autism, according to a recent study involving more than 1,000 preschool children (Stanley et al., 2025). A large study (in a partially overlapping population) including 701 children revealed that 22 to 37% of autistic children had an intense or exclusive, nonsocially oriented interest in letters (Ostrolenk et al., 2024). For autistic children, the odds of having a superior interest in letters were 2.78 times greater than those of nonautistic clinical children of the same age. A systematic review of 82 case reports and 22 group studies involving 315 “hyperlexic” children demonstrated that, depending on the criteria used, up to 20% of autistic children exhibited accelerated abilities in decoding printed characters, which were dissociated from their other abilities (Ostrolenk et al., 2017). Eighty-four percent of hyperlexic individuals had a phenotype within the autistic spectrum. This noninteractive approach to language acquisition can lead to mastering an oral language not spoken within the social environment, resulting in unexpected bilingualism (Dumont et al., 2024; Hindi & Meir, 2025; Zhukova et al., 2023) without prioritizing socially oriented communication (Kissine, 2021).

Can the extraction of calendar rules, following an exposure to written material like calendars, recycle the typical mechanism by which neurotypical children “crack” the oral code? While the primary mode of language is oral, letters and numbers serve as

written notation. Literacy acquisition typically involves a distinct mode of exposure and neural circuitry compared to those supporting oral language acquisition (Dehaene & Cohen, 2007). The structural relationships between written units are typically encountered after mastering oral language and are visually presented, and the samples are systematically arranged and significantly larger.

The interest in randomly encountered calendars may represent a narrowing of focus on letters and numbers, where interest and exposure are circularly related. Evidence of letter and number manipulation is found in 12 calendar calculators, for which hyperlexic behaviors precede the discovery of calendar abilities (Courchesne et al., 2020; Cowan et al., 2004; Goodman, 1972; Heavey, 1996; Motttron, Lemmens, et al., 2006; Patti, 1994; Vulchanova et al., 2012; Young, 1995). For calculators, their exposure to calendar material is often intense; 28 calendar calculators experienced, according to the author, significant exposure to copies of this material (Barnejee, 1975; Benoit et al., 1965; Courchesne et al., 2020; Cowan et al., 2004; Gilmore & Hayes, 1996; Heavey, 1996; Heuyer & Badonnel, 1928; Ho et al., 1991; Hoffman, 1971; Horwitz et al., 1965, 1969; Jensen, 1990; Moriarty et al., 1993; Nurcombe & Parker, 1964; O'Connor & Hermelin, 1992; Olson et al., 2010; Peru, 2023; Pesenti et al., 1999; Puente et al., 2016; Şevik et al., 2010; Young, 1995).

Rather than being incidental, this sequence of interests aligns with the developmental trajectory of oral language in prototypical autism. CC occurs at a time when some autistic children, after a language delay, partly recover oral language. Exposure to calendars coincides with a specific period in autistic oral language acquisition, at the intersection of their language development and interest in structurally organized written material (Barnejee, 1975; Bicakci et al., 2021; Bouvet et al., 2014; Courchesne et al., 2020; Cowan & Carney, 2006; Cowan et al., 2004; Gilmore & Hayes, 1996; Goodman, 1972; Heavey, 1996; Horwitz et al., 1965, 1969; Hurst & Mulhall, 1988; Malhotra et al., 1973; Nelson & Pribor, 1993; Palo & Kivalo, 1977; Patti & Lupinetti, 1993; Rosen, 1981; Shields-Wolfe & Gallagher, 1992; Wallace, 2006; Wallace et al., 2009). Consistently, for 26 CC participants in the literature (Barnejee, 1975; Bouvet et al., 2014; Cowan et al., 2004; Dubischar-Krivic et al., 2009; Gilmore & Hayes, 1996; Heavey, 1996; Heuyer & Badonnel, 1928; Hoffman, 1971; Horwitz et al., 1965; Lafora, 1935; Malhotra et al., 1973; O'Connor & Hermelin, 1984, 1992; O'Connor et al., 2000; Parker et al., 2006; Rosen, 1981; Rubin & Monaghan, 1965; Scheerer et al., 1945; Young & Nettelbeck, 1994), the age of CC awareness among families occurs between 6 and 10 years, coinciding with language recovery after the nonverbal plateau period that characterizes language acquisition in prototypical autistic development (Gagnon et al., 2021).

Typical oral language acquisition requires interaction with peers and caregivers. In contrast, hyperlexic behaviors and CC in autism are learned autonomously through mere exposure to written material (Nation, 1999; Ostrolenk et al., 2017, 2025). Nonsocial learning of calendars aligns with the nonsocial language learning often observed in autism. Accordingly, a meta-analysis on the role of joint attention in language learning in prototypical autism demonstrated that language development, beyond the first words, is not necessarily dependent on joint attention and therefore lacks a social bias (Kissine et al., 2023). This suggests that an early interest in written symbols in autism may lay the groundwork for later calendar abilities. It also indicates that, albeit with some delay and in a nonsocial manner, the ability to decode

complex oral material from mere exposure could be repurposed for written material (including calendars) in autism.

Implicit Learning of Oral Language and CC

L1 acquisition is typically characterized as implicit and self-taught (Moldin & Rubenstein, 2006; Saffran et al., 1996; Ullman, 2001, 2004). Children develop their knowledge of language at a nonconscious level (Fodor, 1983). Even in adulthood, grammatical rules are automatic and controlled by processes not accessible to consciousness during sentence production (Chang et al., 2012). However, these rules can be made explicit post hoc (Ellis, 1994; Karmiloff-Smith, 1992; Perruchet, 2005; Winter & Reber, 1994).

In neurotypical individuals, this mode of learning does not effectively apply to the knowledge of rules that organize written material, such as literacy and, even more so, mathematics. Although some mathematical rules (like multiplication tables) can be automated, explicit learning is needed to improve problem solving (Ziegler et al., 2018). In hyperlexia and CC, written material shares a mode of implicit learning typically devoted to oral language. While calendars involve complex written material, their rules can be mastered and applied implicitly, at a high level of proficiency. Even in adulthood and with good communication abilities, 25 calendar calculators were unable to explicitly describe the processes by which they acquired their ability and produce correct answers to the questions posed to them (Barnejee, 1975; Benoit et al., 1965; Byrd, 1920; Dubischar-Krivec et al., 2009; Heavey, 1996; Heuyer & Badonnel, 1928; Ho et al., 1991; Horwitz et al., 1965, 1969; Howe & Smith, 1988; Hurst & Mulhall, 1988; Malhotra et al., 1973; Moriarty et al., 1993; Nurcombe & Parker, 1964; Olson et al., 2010; Palo & Kivalo, 1977; Parker et al., 2006; Rosen, 1981; Scheerer et al., 1945; Smith & Howe, 1985; Wallace, 2006; Wallace et al., 2009; Young, 1995). CC's ability was discovered by their entourage purely by chance, and to their knowledge, it had not resulted from explicit learning (Abhyankar et al., 1981; Barnejee, 1975; Benoit et al., 1965; Bickel et al., 2021; Bouvet et al., 2014; Courchesne et al., 2020; Cowan et al., 2004; De Marco et al., 2016; Gilmore & Hayes, 1996; Heavey, 1996; Heuyer & Badonnel, 1928; Ho et al., 1991; Hoffman, 1971; Horwitz et al., 1965, 1969; Hurst & Mulhall, 1988; Iavarone et al., 2007; Jensen, 1990; Malhotra et al., 1973; Mottron, Lemmens, et al., 2006; Nurcombe & Parker, 1964; Palo & Kivalo, 1977; Parker et al., 2006; Rosen, 1981; Rubin & Monaghan, 1965; Scheerer et al., 1945; Şevik et al., 2010; Shields-Wolfe & Gallagher, 1992; Thioux et al., 2006; Wallace, 2006; Wallace et al., 2009; Young, 1995).

“Double Articulation” in Oral (and Written) Language and Calendars

Human language is characterized by its “double articulation,” whereby a limited quantity of units, phonemes or letters, are combined at a higher level (morphemes) to form language samples, the interpretation of which involves not focusing on the lower levels. A language level can be interpreted (e.g., in a metalanguage) while being composed linearly of units that cannot be interpreted on the same level. Similarly, the semantic interpretation of sentences depends on the semantic interpretation of words, but sentences are composed of a concatenation of phonemes/graphemes, which themselves cannot be interpreted at the same level. Calendar information, whether an individual date or a calendar regularity, is, at this regard,

the analog of a sentence, made up of first-level units, letters and numbers, forming second-level units, days, weeks, months, and years, themselves linked into complex regularities such as the 28-year rule or leap years. The common “double articulation” of language (oral or written) and calendars as two-level, “doubly articulated” rule systems may also contribute to the extension of the abilities needed to learn and use the former to the benefit of the latter. In autism, the natural preference for large, structured visual patterns—especially those with redundancy and embedding—may reflect a broader human tendency to be drawn to and learn from complex, languagelike structures, which are essential for language acquisition (Mottron et al., 2021) and are characterized by “double articulation.”

First Linguistic References and Anchor Dates

Calculators are generally able to provide information for certain dates (events associated with a particular date, birthdays, film releases). This has allowed the emergence of the concept of “anchor dates.” In the calendar/natural language isomorphism grounding our model, anchor dates have the function taken by referring to natural objects in the acquisition of first words, which are secondarily connected to the lexicosemantic network (Vulchanova et al., 2023), with the difference that these references are not socially mediated. In learning natural language, *joint* referencing represents one of the first steps (Baldwin, 1991). With this exposure to references, the process of categorization takes place, enabling concepts to be discriminated and associated. In neurotypical development, for a word to be acquired, it must be associated with a concept or a meaning (Waxman & Lidz, 2006), which involves at a certain point its differential relations with other words of the lexicon and is constrained by social context. Critically, the memorization of a self-taught, stable, early association between two elements pertaining to two isomorphic levels is not an isolated phenomenon in relation to autism. At least two other examples of equivalent nature, overrepresented in autism, absolute pitch, and synesthesia, “may provide the first basic features of a system which, with the acquisition of later items, may ‘kick start’ the eventual emergence of structured association networks (i.e., musical, or numerical) underlying the outstanding performances” (Pring & Hermelin, 2002, p. 102), albeit in a nonsocial context. Several years after the acquisition of basic literacy knowledge, which allows interest in calendars, anchor dates may ground calendar knowledge in the personal, idiosyncratic, informational context of the calendar calculator, as does absolute pitch for the musical ability and culture of a musician (Di Stefano & Spence, 2024) and as does shared referencing in natural language learning.

Producing Future Dates and Generative Syntax in Language

Calendar rules may be analogous to grammatical rules in language: While neither is consciously accessible (Heavey et al., 2012; Hermelin & O'Connor, 1986; Jensen, 1990; O'Connor & Hermelin, 1984; Young & Nettelbeck, 1994), they successfully constrain the production of “correct” sequences of a complex, structured, symbolic system. Human language includes the generative competence to produce new, well-constructed utterances (Chomsky, 2013) and to give meaning to newly heard utterances, up to a certain length and level of complexity, according to the implicit mastery of syntactical rules shared by speakers (Chomsky, 2014). Repeated exposure to

L1 productions leads to implicit learning of rules, attested by the grammaticality of statements produced explicitly once language has been mastered. It is, however, possible for language-possessing humans to verbalize grammatical errors explicitly and to correct them if necessary. Empirically, syntactic judgment (Barton-Hulsey & Sterling, 2020; Moro et al., 2015) is used to measure a speaker's grammatical rule knowledge.

Calendar calculators can generate future dates and past dates beyond the calendars to which they are exposed (Cowan & Frith, 2009; De Marco et al., 2016; O'Connor et al., 2000). The production of a correct date in response to a future question involves the application of structural rules, such that a correct date can be considered a well-formed calendar statement. The use of these regularities is also attested by the ability to judge the falsity of a date in a rapid manner, which we argue can be considered as a CC analogous of grammaticality judgment. This ability exists in CC, with a similar sensitivity rate for true and false dates (Cowan & Frith, 2009; Minati & Sigala, 2013). Correct judgments on future dates cannot be produced by comparing the presented date with a memorized date. The detection of an error in a calendar statement for a date never encountered in this form would therefore not be made as a mismatch with an episodic remembrance but as the detection of an error in the application of a rule, like what is described in the grammaticality judgment made on a sentence. While the CC generativity goes beyond what can be explained by calendar or episodic memorization, it is still bounded by a certain range that is an analog to the generative competence inherent in language. This generativity is bounded by the limit of years in the past and/or future for which a calendar calculator provides accurate answers above chance level. While we ignore the nature and cause of the limitation in the span of calendar calculators, it is of note that despite the structural possibility of infinite sentences, sentences in oral and written natural language, similarly, do not exceed a certain canonic length.

Calendar Knowledge and Semantic Memory Network Organization

Network models of semantic memory (Collins & Quillian, 1969; Kumar, 2021; for an informed review of its developmental construction in neurotypical and autistic individuals, see Vulchanova et al., 2023) propose that the meaning of a word is organized both hierarchically and as a network. A superordinate category (e.g., furniture) includes several categories sharing common "semes" (wood, domestic utility, etc.). These categories are organized into a semantic knowledge network; each node is included in multiple interconnected categories. For example, a chair is simultaneously a piece of furniture, an object made of wood, and an object with a certain price. Cognitive operations involving semantic memory activate this network multidirectionally: hierarchically (e.g., from chair to furniture), homocategorically (e.g., from chair to armchair), or heterocategorically (e.g., from chair to cat on the chair). This organization is demonstrated by the semantic priming effect (David et al., 2011): Activating elements within the network accelerates responses connected to other nodes, and the effect is stronger the closer the nodes are.

Our CC model assumes the displacement of functions typically used in L1 acquisition onto calendar materials that share a structural similarity with language. One function that could be "displaced" onto calendars is semantic memory (Tulving, 1993), though it is limited by the atypical nature of the material to which it is applied.

Semantic memory is clearly affected in the early years of autistic children, in both their oral language (Ehlen et al., 2020; Norbury et al., 2010) and their early, sometimes precocious, acquisition of written language (Nation, 1999; Ostrolenk et al., 2017; Saldaña et al., 2009). Compared to neurotypical children, autistic children acquire new words more through "shallow encoding" (Craik & Lockhart, 1972) and have difficulty building a semantic memory through oral means. Even when tested in autistic children with more developed oral language skills, some aspects of their semantics may still be atypical or impaired (Hartley & Allen, 2015; Vulchanova et al., 2023). However, their semantic organization becomes more typical as they reach adulthood, although some atypicalities persist (Desaunay et al., 2020). This is evident in the circumscribed encyclopedic knowledge characteristic of verbal autistics once language is acquired (Klin et al., 2007).

The possibility that a semantic-type network can develop later in life for nonsocial material (calendar) suggests that the early semantic deficits observed in autistic children may be linked to the inherently social nature of oral language. However, semantic knowledge can still be acquired later via alternative, nonsocial modalities. We propose that the ability to construct, maintain, and activate complex semantic networks, typically used for verbal entities during language acquisition, can be extended to include access to calendar information. In calendar calculators, this may take the form of a "calendar information network," where multiple interconnected elements support rapid retrieval.

The multidirectional structure of semantic memory, for instance, shows meaningful parallels with the ability to answer reverse calendar questions. This type of multidirectional access is similar to the retrieval of semantic information from verbal cues in neurotypical individuals (Motttron, Lemmens, et al., 2006). The calculator's ability to answer a wide variety of reverse questions implies flexible (Hermelin & O'Connor, 1986; Thioux et al., 2006), multidirectional (Motttron, Lemmens, et al., 2006), or random (Horwitz et al., 1969) access to verbal information from verbal questions. This suggests that calendar information is organized in a structured way in memory (Heavey et al., 2012; Smith & Howe, 1985). This network can be explored in a multidirectional manner, through both simple questions and inverse questions, to the same extent that semantic memory authorizes multidirectional recall of information possessing a common property (e.g., recalling as quickly "Shere Khan's," "Big Carnivore with stripes," "Mowgli's worst enemy," "the largest and most dangerous Bengal cat"; Motttron, Lemmens, et al., 2006). This multidirectional access prevents reverse questions from being an effect of episodic memory, especially since it has been observed in a calculator showing a deficit in episodic memory (Olson et al., 2010).

The analogy between the structure of calendar information and typical semantic memory is empirically demonstrated by certain types of priming tasks comparing the RT of pairs of dates with congruent (sharing some structural similarity, such as the same template, the same weekday, and thus the same response) and incongruent (no link) priming (Cowan et al., 2003; De Marco et al., 2016; Hermelin & O'Connor, 1986; Wallace et al., 2009; Young, 1995). The "saving score" for pairs of related dates indicates that similarities among calendar information can optimize performance (De Marco et al., 2016; Hermelin & O'Connor, 1986; O'Connor et al., 2000; Wallace, 2006; Wallace et al., 2009). Another characteristic pertaining to semantic memory and structuration of calendar information is that answers to calendar questions are generated

quickly and with little cognitive effort. The “I just know it” responses of calculators when asked about their knowledge of dates are also characteristic of semantic memory information (Tulving, 1993, p. 49, in Parker et al., 2006). Taken together, these findings support our comparison between calendar knowledge and certain properties of semantic organization. Despite the atypical way in which it entered the network (exposure to written information; here calendars), semantic-type, multidirectional access to its components is possible once acquired.

CC as a “Chimera” of Oral and Written Language

In neurotypically developing children, oral language is a main factor in the development of reading skills, and vocabulary is the best predictor of later reading comprehension (National Reading Panel et al., 2000; Rayner et al., 2001). The visual recognition of written words is closely related to the previous knowledge of a word and its meaning (Cain et al., 2004), and the phonological resources acquired in oral language are involved in reading acquisition (Snowling et al., 2000). In neurotypical development, functional magnetic resonance imaging studies have shown a correlation between reading performance and cerebral activation for speech, with a written–oral coactivation only observed in readers, highlighting the development of new connections between reading and language networks (Chyl et al., 2018). Typical reading acquisition also results in the specialization of left ventral visual areas for the perceptual treatment of strings of letters: the visual word form area (Dehaene-Lambertz et al., 2018). This left lateralization for letters is thought to emerge even before formal reading acquisition, in children with limited alphabetic knowledge (Lochy et al., 2016). Overall, the successful acquisition of reading skills in typical development children is strongly dependent on oral language, communication, and social skills. Conversely, difficulties in oral language development are expected to affect literacy skills.

In autism, neuroimaging studies have shown reduced activation in brain areas involved in semantic processing (Harris et al., 2006), more right-lateralized neurophysiological connectivity during word-related tasks (Kikuchi et al., 2013; Ogawa et al., 2019), reduced connectivity between visual and semantic processing areas (Bednarz et al., 2017), and reduced intrahemispheric and interhemispheric

connectivity in the prefrontal cortex, which is involved in verbal fluency, in autistics with low reading comprehension (Chan et al., 2022). These neural differences are consistent with the dissociation between superior decoding and poor comprehension in autism.

It is precisely because of the differences between the written and spoken codes that autistic people can master the former more easily than the latter. Our position is that some prototypical autistic children, including calendar calculators, can use written language to acquire oral language. CC would be a developmental chimera resulting from applying to complex written material the type of abilities required to master oral language (Figure 2).

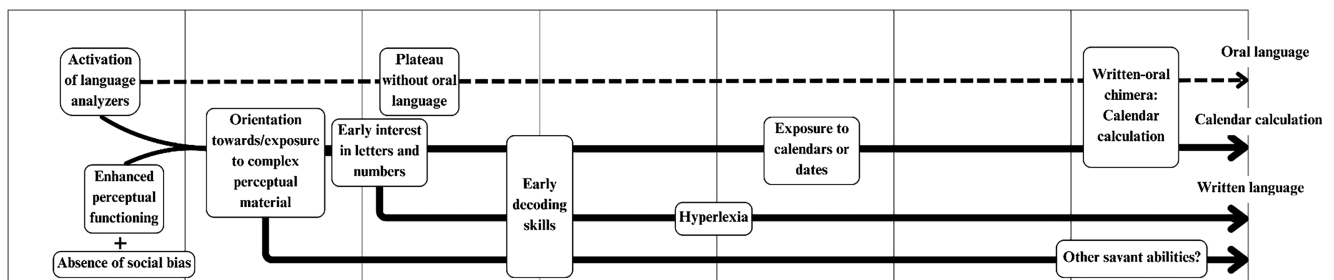
Conclusion

We propose that calendars are a source of information available in the environment of autistic children, which, despite being restricted, written, and noncommunicative, partially overlaps with natural language. CC in autism can be explained by the fractional and delayed redirection of the innate mechanisms and motivations by which neurotypical children implicitly learn and master oral language. The limited interest in social rewards inherent to autism, combined with the self-gratification provided by the visual and mental manipulation of calendar-related information, leads to a preferential, superior, and spontaneous orientation in autism to large sets of noninteractive information.

This model incorporates a “language” component to the enhanced perceptual functioning model, consistent with its recent extension to a reversal in the brain’s information processing hierarchy (Bernhardt et al., 2025). While perceptual recognition of redundancy between large sets of data remains a key element, it does not fully explain the orientation toward these complex structures nor the ability to generatively manipulate such complex information. A heightened interest in written codes may drive the perceptual discovery of pattern redundancies and large-scale isomorphisms within such systems, including the structure of the calendar. Interest in calendars, and secondarily the mastering of their regularities, would be possible because of the initial orientation toward written material presenting regularities such as letters and numbers, the partial material overlap, the deep structural kinship, and the contextual similarity between calendars and human language. CC may therefore constitute

Figure 2

Autistic Developmental Sequence of Oral, Written Code, and Calendar Calculation Acquisition



Note. In autistic development, language analyzers cannot be exercised on the oral language emitted by peers due to the absence of social bias. They are diverted to perceptual objects, including letters and numbers to which children are exposed through books or screens, resulting in early interests in letters and numbers and self-taught decoding skills. Incidental exposure to complex written materials containing letters and numbers, such as calendars, may trigger the language analyzers to apply them to calendars. This result of implicit learning of calendar rules, calendar calculation, is a chimera between oral language and written language. The acquisition of oral language is delayed.

an example of self-taught and implicit learning of a subset of human structured systems, allowing the generation of a new, “grammatically correct” material to which the person has never been exposed.

This investment can occur during the crucial period for language acquisition in autistic children. It follows the plateau where autistic children are mostly nonverbal. The deviation of neurotypical human language analyzers would be a consequence of the autistic bifurcation by which the social bias disappears and oral language learning stops until its late, abrupt, and frequently incomplete recovery (Mottron & Gagnon, 2023). Written instantiations of language, letters and numbers, and subsequently any realization close to the “double articulation” specific to human language such as calendars, would be likely to be invested like L1. The detection of calendar regularities would direct some autistic children toward this type of material, in the same way that the detection of phonetic, referential, and syntactic regularities in a social context supports typical language acquisition—with the difference that in autism, it could be learned in a predominantly non-interactive, noncommunicative way. On the other hand, the mastery of CC presents a cognitively opportunistic and idiosyncratic character. The whole of cognition (perception, memory) would be put to contribution in a way idiosyncratic to each calculator depending on the context, thus explaining the variability of the empirically demonstrated strategies. Calculators will therefore use the most efficient strategy to respond.

The language model must now be tested by a priori hypotheses, filling the gaps in the observations from which it was constructed. The comparison between savant and nonsavant abilities must consider the fact that nonautistic calculators do not represent a control group “all things being equal,” due to a history of acquisition of the capacity that is not comparable. Neither can noncalculating autistics be used as ideal controls, due to a strongly divergent level of expertise. An in-depth, individualized investigation of autistic language regression, of the plateau without language, of the appearance of an interest in the written code, and of the resumption of oral language will have to be carried out as soon as the calendar capacity manifests. It should be compared to their equivalent in other atypical autistic abilities linked to language, such as hyperlexia. The demonstration of the linguistic nature of CC can also be done through intrasubject brain imaging comparisons between verbal and calendar tasks of a similar nature, comparing the contemporary activation of a syntactic judgment and a judgment of accuracy on calendar information, between linguistic and calendar priming, or between any other criterion of similarity between language and calendar that we have mentioned. It remains to be established how this mode of learning can be extended to other “savant abilities” and could be, at least partially, redirected toward oral language and promote its mastery in nonverbal or minimally verbal autistic people.

References

- Abhyankar, R. R., Thatte, S. S., & Doongaji, D. R. (1981). Idiot savant. *Journal of Postgraduate Medicine*, 27(1), 44–47.
- Altshuler, K. Z., & Brebbia, R. (1968). Sleep patterns and EEG recordings in twin idiot savants. *Diseases of the Nervous System*, 29(11), 772–774.
- Ashwin, E., Ashwin, C., Rhydderch, D., Howells, J., & Baron-Cohen, S. (2009). Eagle-eyed visual acuity: An experimental investigation of enhanced perception in autism. *Biological Psychiatry*, 65(1), 17–21. <https://doi.org/10.1016/j.biopsych.2008.06.012>
- Baldwin, D. A. (1991). Infants' contribution to the achievement of joint reference. *Child Development*, 62(5), 875–890. <https://doi.org/10.1111/j.1467-8624.1991.tb01577.x>
- Barnejee, G. (1975). Another calendar calculator. *Indian Journal of Psychiatry*, 17, 144–146.
- Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, 6(6), 248–254. [https://doi.org/10.1016/S1364-6613\(02\)01904-6](https://doi.org/10.1016/S1364-6613(02)01904-6)
- Baron-Cohen, S. (2006). The hyper-systemizing, assortative mating theory of autism. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, 30(5), 865–872. <https://doi.org/10.1016/j.pnpbp.2006.01.010>
- Baron-Cohen, S. (2008). Autism, hypersystemizing, and truth. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, 61(1), 64–75. <https://doi.org/10.1080/17470210701508749>
- Baron-Cohen, S., Bor, D., Billington, J., Asher, J., Wheelwright, S., & Ashwin, C. (2007). Savant memory in a man with colour form-number synaesthesia and asperger. *Journal of Consciousness Studies*, 14(9–10), 237–251.
- Barton-Hulsey, A., & Sterling, A. (2020). Grammatical judgment and production in male participants with idiopathic autism spectrum disorder. *Clinical Linguistics & Phonetics*, 34(12), 1088–1111. <https://doi.org/10.1080/02699206.2020.1719208>
- Beccaria, F., Gagliardi, G., & Kissine, M. (2025). Atypical regional accent in autistic children: A perception study. *Autism Research*, 18(2), 415–426. <https://doi.org/10.1002/aur.3300>
- Bednarz, H. M., Maximo, J. O., Murdaugh, D. L., O'Kelley, S., & Kana, R. K. (2017). “Decoding versus comprehension”: Brain responses underlying reading comprehension in children with autism. *Brain and Language*, 169, 39–47. <https://doi.org/10.1016/j.bandl.2017.01.002>
- Benoit, G., Poncin, C., & Poncin, M. (1965). A propos of a calendar calculator (historical and theoretical reflections). *Annales Médico-Psychologiques*, 123, 316–323.
- Bernhardt, B. C., Valk, S. L., Hong, S. J., Soulières, I., & Mottron, L. (2025). Autism-related shifts in the brain's information processing hierarchy. *Trends in Cognitive Sciences*. Advance online publication. <https://doi.org/10.1016/j.tics.2025.04.008>
- Bicakci, M., Koksall, M. S., & Baloglu, M. (2021). A savant case from Turkey: Cognitive functions and calendar calculation. *Clinical Psychology and Special Education*, 10(1), 1–14. https://www.researchgate.net/publication/350892163_A_Savant_Case_from_Turkey_Cognitive_Functions_and_Calendar_Calculation
- Bled, C., Guillon, Q., Mottron, L., Soulières, I., & Bouvet, L. (2024). Visual mental imagery abilities in autism. *Autism Research*, 17(10), 2064–2078. <https://doi.org/10.1002/aur.3192>
- Boddaert, N., Barthélémy, C., Poline, J.-B., Samson, Y., Brunelle, F., & Zilbovicius, M. (2005). Autism: Functional brain mapping of exceptional calendar capacity. *The British Journal of Psychiatry*, 187(1), 83–86. <https://doi.org/10.1192/bjp.187.1.83>
- Bölte, S., Schlitt, S., Gapp, V., Hainz, D., Schirman, S., Poustka, F., Weber, B., Freitag, C., Ciaramidaro, A., & Walter, H. (2012). A close eye on the eagle-eyed visual acuity hypothesis of autism. *Journal of Autism and Developmental Disorders*, 42(5), 726–733. <https://doi.org/10.1007/s10803-011-1300-3>
- Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., Burack, J. A., & Mottron, L. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not Asperger syndrome. *Neuropsychologia*, 48(9), 2465–2475. <https://doi.org/10.1016/j.neuropsychologia.2010.04.020>
- Bouvet, L., Amsellem, F., Maruani, A., Tonus-Vic Dupont, A., Mathieu, A., Bourgeron, T., Delorme, R., & Mottron, L. (2019). Synesthesia & autistic features in a large family: Evidence for spatial imagery as a common factor. *Behavioural Brain Research*, 362, 266–272. <https://doi.org/10.1016/j.bbr.2019.01.014>
- Bouvet, L., Donnadieu, S., Valdois, S., Caron, C., Dawson, M., & Mottron, L. (2014). Veridical mapping in savant abilities, absolute pitch, and

- synesthesia: An autism case study. *Frontiers in Psychology*, 5, Article 106. <https://doi.org/10.3389/fpsyg.2014.00106>
- Byrd, H. (1920). A case of phenomenal memorizing by a feeble-minded Negro. *Journal of Applied Psychology*, 4(2–3), 202–206. <https://doi.org/10.1037/h0074272>
- Cain, K., Oakhill, J., & Lemmon, K. (2004). Individual differences in the inference of word meanings from context: The influence of reading comprehension, vocabulary knowledge, and memory capacity. *Journal of Educational Psychology*, 96(4), 671–681. <https://doi.org/10.1037/0022-0663.96.4.671>
- Caron, M. J., Motttron, L., Berthiaume, C., & Dawson, M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. *Brain*, 129(7), 1789–1802. <https://doi.org/10.1093/brain/awl072>
- Carroll, L. (1887). To find the day of the week for any given date. *Nature*, 35(909), Article 517. <https://doi.org/10.1038/035517a0>
- Chan, M. M. Y., Chan, M. C., Yeung, M. K., Wang, S. M., Liu, D., & Han, Y. M. Y. (2022). Aberrant prefrontal functional connectivity during verbal fluency test is associated with reading comprehension deficits in autism spectrum disorder: An fNIRS study. *Frontiers in Psychology*, 13, Article 984777. <https://doi.org/10.3389/fpsyg.2022.984777>
- Chang, F., Janciauskas, M., & Fitz, H. (2012). Language adaptation and learning: Getting explicit about implicit learning. *Language and Linguistics Compass*, 6(5), 259–278. <https://doi.org/10.1002/lnc3.337>
- Chomsky, N. (2013). *Topics in the theory of generative grammar*. De Gruyter Mouton.
- Chomsky, N. (2014). *Aspects of the theory of syntax* (Vol. 11). MIT Press.
- Chyl, K., Kossowski, B., Dębska, A., Łuniewska, M., Banaszkiewicz, A., Żelechowska, A., Frost, S. J., Mencl, W. E., Wypych, M., Marchewka, A., Pugh, K. R., & Jednoróg, K. (2018). Prereader to beginning reader: Changes induced by reading acquisition in print and speech brain networks. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 59(1), 76–87. <https://doi.org/10.1111/jcpp.12774>
- Cohn, M. (2007). *The mathematics of the calendar*. Lulu Press.
- Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 8(2), 240–247. [https://doi.org/10.1016/S0022-5371\(69\)80069-1](https://doi.org/10.1016/S0022-5371(69)80069-1)
- Courchesne, V., Langlois, V., Gregoire, P., St-Denis, A., Bouvet, L., Ostrolenk, A., & Motttron, L. (2020). Interests and strengths in autism, useful but misunderstood: A pragmatic case-study. *Frontiers in Psychology*, 11, Article 569339. <https://doi.org/10.3389/fpsyg.2020.569339>
- Cowan, R., & Carney, D. P. (2006). Calendrical savants: Exceptionality and practice. *Cognition*, 100(2), B1–B9. <https://doi.org/10.1016/j.cognition.2005.08.001>
- Cowan, R., & Frith, C. (2009). Do calendrical savants use calculation to answer date questions? A functional magnetic resonance imaging study. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1417–1424. <https://doi.org/10.1098/rstb.2008.0323>
- Cowan, R., O'Connor, N., & Samella, K. (2003). The skills and methods of calendrical savants. *Intelligence*, 31(1), 51–65. [https://doi.org/10.1016/S0160-2896\(02\)00119-8](https://doi.org/10.1016/S0160-2896(02)00119-8)
- Cowan, R., Stainthorpe, R., Kapnogianni, S., & Anastasiou, M. (2004). The development of calendrical skills. *Cognitive Development*, 19(2), 169–178. <https://doi.org/10.1016/j.cogdev.2003.11.005>
- Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11(6), 671–684. [https://doi.org/10.1016/S0022-5371\(72\)80001-X](https://doi.org/10.1016/S0022-5371(72)80001-X)
- David, N., R Schneider, T., Vogetley, K., & Engel, A. K. (2011). Impairments in multisensory processing are not universal to the autism spectrum: No evidence for crossmodal priming deficits in Asperger syndrome. *Autism Research*, 4(5), 383–388. <https://doi.org/10.1002/aur.210>
- Dawson, M., Soulières, I., Ann Gernsbacher, M., & Motttron, L. (2007). The level and nature of autistic intelligence. *Psychological Science*, 18(8), 657–662. <https://doi.org/10.1111/j.1467-9280.2007.01954.x>
- De Marco, M., Iavarone, A., Santoro, G., & Carlomagno, S. (2016). Brief report: Two day-date processing methods in an autistic savant calendar calculator. *Journal of Autism and Developmental Disorders*, 46(3), 1096–1102. <https://doi.org/10.1007/s10803-015-2626-z>
- Degré-Pelletier, J., Danis, É., Thérien, V. D., Bernhardt, B., Barbeau, E. B., & Soulières, I. (2024). Differential neural correlates underlying visuospatial versus semantic reasoning in autistic children. *Cerebral Cortex*, 34(13), 19–29. <https://doi.org/10.1093/cercor/bhae093>
- Dehaene, S., & Cohen, L. (2007). Cultural recycling of cortical maps. *Neuron*, 56(2), 384–398. <https://doi.org/10.1016/j.neuron.2007.10.004>
- Dehaene-Lambertz, G., Monzalvo, K., & Dehaene, S. (2018). The emergence of the visual word form: Longitudinal evolution of category-specific ventral visual areas during reading acquisition. *PLOS Biology*, 16(3), Article e2004103. <https://doi.org/10.1371/journal.pbio.2004103>
- Desaunay, P., Briant, A. R., Bowler, D. M., Ring, M., Gérardin, P., Baleyte, J. M., Guénolé, F., Eustache, F., Parienti, J. J., & Guillery-Girard, B. (2020). Memory in autism spectrum disorder: A meta-analysis of experimental studies. *Psychological Bulletin*, 146(5), 377–410. <https://doi.org/10.1037/bul0000225>
- Di Stefano, N., & Spence, C. (2024). Should absolute pitch be considered as a unique kind of absolute sensory judgment in humans? A systematic and theoretical review of the literature. *Cognition*, 249, Article 105805. <https://doi.org/10.1016/j.cognition.2024.105805>
- Dorman, C. (1991). Exceptional calendar calculation ability after early left hemispherectomy. *Brain and Cognition*, 15(1), 26–36. [https://doi.org/10.1016/0278-2626\(91\)90013-X](https://doi.org/10.1016/0278-2626(91)90013-X)
- Dubischar-Krivec, A. M., Bölte, S., Braun, C., Poustka, F., Birbaumer, N., & Neumann, N. (2014). Neural mechanisms of savant calendar calculating in autism: An MEG-study of few single cases. *Brain and Cognition*, 90, 157–164. <https://doi.org/10.1016/j.bandc.2014.07.003>
- Dubischar-Krivec, A. M., Neumann, N., Poustka, F., Braun, C., Birbaumer, N., & Bölte, S. (2009). Calendar calculating in savants with autism and healthy calendar calculators. *Psychological Medicine*, 39(8), 1355–1363. <https://doi.org/10.1017/S0033291708004601>
- Dumont, C., Belenger, M., Eigsti, I. M., & Kissine, M. (2024). Enhanced pitch discrimination in autistic children with unexpected bilingualism. *Autism Research*, 17(9), 1844–1852. <https://doi.org/10.1002/aur.3221>
- Ehlen, F., Roepke, S., Klostermann, F., Baskow, I., Geise, P., Belica, C., Tiedt, H. O., & Behnia, B. (2020). Small semantic networks in individuals with autism spectrum disorder without intellectual impairment: A verbal fluency approach. *Journal of Autism and Developmental Disorders*, 50(11), 3967–3987. <https://doi.org/10.1007/s10803-020-04457-9>
- Ellis, N. (1994). Implicit and explicit language learning. *Implicit and Explicit Learning of Languages*, 27(2), 79–114.
- Fauville, A. (1936). Un débile mental calculeur prodige [A calculating prodigy with mental disabilities]. *Revue Beige Pédagogie*, 17, 338–344.
- Fehr, T., Wallace, G. L., Erhard, P., & Herrmann, M. (2011). The neural architecture of expert calendar calculation: A matter of strategy? *Neurocase*, 17(4), 360–371. <https://doi.org/10.1080/13554794.2010.532135>
- Fodor, J. D. (1983). Phrase structure parsing and the island constraints. *Linguistics and Philosophy*, 6(2), 163–223. <https://doi.org/10.1007/BF00635643>
- Fortunado, I. T. (2014). Julian calendar and Gregorian calendar algorithms. *International Journal of Mathematics, Engineering & Technology*, 9(1). <https://isidore.co/misc/Physics%20papers%20and%20books/Zotero/storage/UIHU245Z/794.html>
- Gaffrey, M. S., Kleinhans, N. M., Haist, F., Akshoomoff, N., Campbell, A., Courchesne, E., & Müller, R. A. (2007). Atypical [corrected] participation of visual cortex during word processing in autism: An fMRI study of semantic decision. *Neuropsychologia*, 45(8), 1672–1684. <https://doi.org/10.1016/j.neuropsychologia.2007.01.008>
- Gagnon, D., Zeribi, A., Douard, É., Courchesne, V., Rodríguez-Herreros, B., Huguet, G., Jacquemont, S., Lom, M. A., & Motttron, L. (2021). Bayonet-

- shaped language development in autism with regression: A retrospective study. *Molecular Autism*, 12(1), Article 35. <https://doi.org/10.1186/s13229-021-00444-8>
- Gilmore, L., & Hayes, A. (1996). Asperger's syndrome: A case diagnosed in late adolescence. *Clinical Child Psychology and Psychiatry*, 1(3), 431–439. <https://doi.org/10.1177/1359104596013010>
- Goodman, J. (1972). A case study of an “autistic-savant”: Mental function in the psychotic child with markedly discrepant abilities. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 13(4), 267–278. <https://doi.org/10.1111/j.1469-7610.1972.tb01153.x>
- Happé, F. (2018). Why are savant skills and special talents associated with autism? *World Psychiatry*, 17(3), 280–281. <https://doi.org/10.1002/wps.20552>
- Happé, F., & Frith, U. (1996). The neuropsychology of autism. *Brain*, 119(4), 1377–1400. <https://doi.org/10.1093/brain/119.4.1377>
- Happé, F., & Vital, P. (2009). What aspects of autism predispose to talent? *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1369–1375. <https://doi.org/10.1098/rstb.2008.0332>
- Harlow, J. M. (1848). Passage of an iron rod through the head. *Boston Medical and Surgical Journal*, 39(20), 389–393. <https://doi.org/10.1056/NEJM184812130392001>
- Harris, G. J., Chabris, C. F., Clark, J., Urban, T., Aharon, I., Steele, S., McGrath, L., Condouris, K., & Tager-Flusberg, H. (2006). Brain activation during semantic processing in autism spectrum disorders via functional magnetic resonance imaging. *Brain and Cognition*, 61(1), 54–68. <https://doi.org/10.1016/j.bandc.2005.12.015>
- Hartley, C., & Allen, M. L. (2015). Iconicity influences how effectively minimally verbal children with autism and ability-matched typically developing children use pictures as symbols in a search task. *Autism*, 19(5), 570–579. <https://doi.org/10.1177/1362361314536634>
- Heaton, P., & Wallace, G. L. (2004). Annotation: The savant syndrome. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 45(5), 899–911. <https://doi.org/10.1111/j.1469-7610.2004.t01-1-00284.x>
- Heavey, L. J. (1996). *Memory in the calendar calculating savant* [Doctoral dissertation]. Goldsmiths, University of London.
- Heavey, L. J., Hermelin, B., Crane, L., & Pring, L. (2012). The structure of savant calendrical knowledge. *Developmental Medicine and Child Neurology*, 54(6), 507–513. <https://doi.org/10.1111/j.1469-8749.2012.04250.x>
- Heavey, L. J., Pring, L., & Hermelin, B. (1999). A date to remember: The nature of memory in savant calendrical calculators. *Psychological Medicine*, 29(1), 145–160. <https://doi.org/10.1017/S0033291798007776>
- Hermelin, B. (2001). *Bright splinters of the mind: A personal story of research with autistic savants*. Jessica Kingsley Publishers.
- Hermelin, B., & O'Connor, N. (1986). Idiot savant calendrical calculators: Rules and regularities. *Psychological Medicine*, 16(4), 885–893. <https://doi.org/10.1017/S0033291700011892>
- Heuyer, G., & Badonnel, M. (1928). D  bile Calculateur du Calendrier [Dumb calendar calculator]. *L'Enc  phale*, 23, 610–614.
- Heuyer, G., Dauphin, A., & Lebovici, S. (1946). A stupid calendar calculator. *Annales M  dico-Psychologiques*, 104(3), 231–233.
- Hill, A. L. (1975). An investigation of calendar calculating by an idiot savant. *The American Journal of Psychiatry*, 132(5), 557–560. <https://doi.org/10.1176/ajp.132.5.557>
- Hindi, I., & Meir, N. (2025). Different paths to multilingualism in Autism Spectrum Disorder (ASD): Naturalistic and non-interactive. *Journal of Child Language*. Advance online publication. <https://doi.org/10.1017/S0305000924000540>
- Ho, E. D., Tsang, A. K., & Ho, D. Y. (1991). An investigation of the calendar calculation ability of a Chinese calendar savant. *Journal of Autism and Developmental Disorders*, 21(3), 315–327. <https://doi.org/10.1007/BF02207328>
- Hoffman, E. (1971). The idiot savant: A case report and a review of explanations. *Mental Retardation*, 9(4), 18–21.
- Horwitz, W. A., Deming, W. E., & Winter, R. F. (1969). A further account of the idiots savants, experts with the calendar. *The American Journal of Psychiatry*, 126(3), 412–415. <https://doi.org/10.1176/ajp.126.3.412>
- Horwitz, W. A., Kestenbaum, C., Person, E., & Jarvik, L. (1965). Identical win—“Idiot savants”—Calendar calculators. *The American Journal of Psychiatry*, 121(11), 1075–1079. <https://doi.org/10.1176/ajp.121.11.1075>
- Howe, M. J., & Smith, J. (1988). Calendar calculating in ‘idiots savants’: How do they do it? *British Journal of Psychology*, 79(3), 371–386. <https://doi.org/10.1111/j.2044-8295.1988.tb02296.x>
- Howlin, P. (2012). Understanding savant skills in autism. *Developmental Medicine and Child Neurology*, 54(6), Article 484. <https://doi.org/10.1111/j.1469-8749.2012.04244.x>
- Howlin, P., Goode, S., Hutton, J., & Rutter, M. (2009). Savant skills in autism: Psychometric approaches and parental reports. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1359–1367. <https://doi.org/10.1098/rstb.2008.0328>
- Hughes, J. E. A., Gruffydd, E., Simner, J., & Ward, J. (2019). Synaesthetes show advantages in savant skill acquisition: Training calendar calculation in sequence-space synaesthesia. *Cortex*, 113, 67–82. <https://doi.org/10.1016/j.cortex.2018.11.023>
- Hughes, J. E. A., Simner, J., Baron-Cohen, S., Treffert, D. A., & Ward, J. (2017). Is synaesthesia more prevalent in autism spectrum conditions? Only where there is prodigious talent. *Multisensory Research*, 30(3–5), 391–408. <https://doi.org/10.1163/22134808-00002558>
- Hurst, L. C., & Mulhall, D. J. (1988). Another calendar savant. *The British Journal of Psychiatry*, 152(2), 274–277. <https://doi.org/10.1192/bjp.152.2.274>
- Iavarone, A., Patruno, M., Galeone, F., Chieffi, S., & Carlomagno, S. (2007). Brief report: Error pattern in an autistic savant calendar calculator. *Journal of Autism and Developmental Disorders*, 37(4), 775–779. <https://doi.org/10.1007/s10803-006-0190-2>
- Jacques, C., Courchesne, V., Meilleur, A. S., Mineau, S., Ferguson, S., Cousineau, D., Labbe, A., Dawson, M., & Motttron, L. (2018). What interests young autistic children? An exploratory study of object exploration and repetitive behavior. *PLOS ONE*, 13(12), Article e0209251. <https://doi.org/10.1371/journal.pone.0209251>
- Jensen, A. R. (1990). Speed of information processing in a calculating prodigy. *Intelligence*, 14(3), 259–274. [https://doi.org/10.1016/0160-2896\(90\)90019-P](https://doi.org/10.1016/0160-2896(90)90019-P)
- Karmiloff-Smith, A. (1992). Nature, nurture and PDP: Preposterous developmental postulates? *Connection Science*, 4(3–4), 253–269. <https://doi.org/10.1080/09540099208946618>
- Kennedy, D. P., & Squire, L. R. (2007). An analysis of calendar performance in two autistic calendar savants. *Learning & Memory*, 14(8), 533–538. <https://doi.org/10.1101/lm.653607>
- Kikuchi, M., Yoshimura, Y., Shitamichi, K., Ueno, S., Hirosawa, T., Munesue, T., Ono, Y., Tsubokawa, T., Haruta, Y., Oi, M., Niida, Y., Remijn, G. B., Takahashi, T., Suzuki, M., Higashida, H., & Minabe, Y. (2013). A custom magnetoencephalography device reveals brain connectivity and high reading/decoding ability in children with autism. *Scientific Reports*, 3(1), Article 1139. <https://doi.org/10.1038/srep01139>
- Kissine, M. (2021). Autism, constructionism, and nativism. *Language*, 97(3), e139–e160. <https://doi.org/10.1353/lan.2021.0055>
- Kissine, M., Saint-Denis, A., & Motttron, L. (2023). Language acquisition can be truly atypical in autism: Beyond joint attention. *Neuroscience and Biobehavioral Reviews*, 153, Article 105384. <https://doi.org/10.1016/j.neubiorev.2023.105384>
- Klin, A., Danovitch, J. H., Merz, A. B., & Volkmar, F. R. (2007). Circumscribed interests in higher functioning individuals with autism spectrum disorders: An exploratory study. *Research and Practice for Persons with Severe Disabilities*, 32(2), 89–100. <https://doi.org/10.2511/rpsd.32.2.89>

- Kumar, A. A. (2021). Semantic memory: A review of methods, models, and current challenges. *Psychonomic Bulletin & Review*, 28(1), 40–80. <https://doi.org/10.3758/s13423-020-01792-x>
- Lafora, G. R. (1935). Etude psychologique d'une débile mentale calculatrice du calendrier [Psychological study of a mentally defective calendar calculator]. *L'Encéphale: Revue de psychiatrie clinique biologique et thérapeutique*, 30, 309–337.
- Lochy, A., Van Reybroeck, M., & Rossion, B. (2016). Left cortical specialization for visual letter strings predicts rudimentary knowledge of letter-sound association in preschoolers. *Proceedings of the National Academy of Sciences of the United States of America*, 113(30), 8544–8549. <https://doi.org/10.1073/pnas.1520366113>
- Malhotra, H. K., Khanna, B. C., & Verma, S. K. (1973). Idiot-savant: Review with a case report. *Indian Journal of Psychiatry*, 15(1), 49–55.
- Malkoff, K. M. (1982). *A neuropsychological investigation of an "autistic savant" process in an autistic population* [Doctoral dissertation]. The Ohio state University.
- Mayr, J. (1959). Week-days and mathematics. *Mathematical Gazette*, 43(344), 81–84. <https://doi.org/10.2307/3610177>
- Meilleur, A. A. S., Jelenic, P., & Mottron, L. (2015). Prevalence of clinically and empirically defined talents and strengths in autism. *Journal of Autism and Developmental Disorders*, 45(5), 1354–1367. <https://doi.org/10.1007/s10803-014-2296-2>
- Miller, L. K. (1998). Defining the savant syndrome. *Journal of Developmental and Physical Disabilities*, 10(1), 73–85. <https://doi.org/10.1023/A:1022813601762>
- Miller, L. K. (1999). The savant syndrome: Intellectual impairment and exceptional skill. *Psychological Bulletin*, 125(1), 31–46. <https://doi.org/10.1037/0033-2909.125.1.31>
- Milner, B. (1962). Les troubles de la memoire accompagnant des lesions hippocampiques bilaterales [Memory disorders accompanying bilateral hippocampal lesions]. *Physiologie de l'hippocampe*, 107, 257–272.
- Minati, L., & Sigala, N. (2013). Effective connectivity reveals strategy differences in an expert calculator. *PLOS ONE*, 8(9), Article e73746. <https://doi.org/10.1371/journal.pone.0073746>
- Moldin, S. O., & Rubenstein, J. L. (2006). Language in autism. In S. O. Moldin & J. L. R. Rubenstein (Eds.), *Dans understanding autism* (pp. 195–224). CRC Press. <https://doi.org/10.1201/9781420004205-14>
- Moriarty, J., Ring, H. A., & Robertson, M. M. (1993). An idiot savant calendrical calculator with Gilles de la Tourette syndrome: Implications for an understanding of the savant syndrome. *Psychological Medicine*, 23(4), 1019–1021. <https://doi.org/10.1017/S0033291700026477>
- Moro, A., Bambini, V., Bosia, M., Anselmetti, S., Riccaboni, R., Cappa, S. F., Smeraldi, E., & Cavallaro, R. (2015). Detecting syntactic and semantic anomalies in schizophrenia. *Neuropsychologia*, 79(Part A), 147–157. <https://doi.org/10.1016/j.neuropsychologia.2015.10.030>
- Mottron, L., & Belleville, S. (1993). A study of perceptual analysis in a high-level autistic subject with exceptional graphic abilities. *Brain and Cognition*, 23(2), 279–309. <https://doi.org/10.1006/brcg.1993.1060>
- Mottron, L., & Belleville, S. (1995). Perspective production in a savant autistic draughtsman. *Psychological Medicine*, 25(3), 639–648. <https://doi.org/10.1017/S0033291700033547>
- Mottron, L., Bouvet, L., Bonnel, A., Samson, F., Burack, J. A., Dawson, M., & Heaton, P. (2013). Veridical mapping in the development of exceptional autistic abilities. *Neuroscience and Biobehavioral Reviews*, 37(2), 209–228. <https://doi.org/10.1016/j.neubiorev.2012.11.016>
- Mottron, L., Dawson, M., & Soulières, I. (2009). Enhanced perception in savant syndrome: Patterns, structure and creativity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1385–1391. <https://doi.org/10.1098/rstb.2008.0333>
- Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, 36(1), 27–43. <https://doi.org/10.1007/s10803-005-0040-7>
- Mottron, L., & Gagnon, D. (2023). Prototypical autism: New diagnostic criteria and asymmetrical bifurcation model. *Acta Psychologica*, 237, Article 103938. <https://doi.org/10.1016/j.actpsy.2023.103938>
- Mottron, L., Lemmens, K., Gagnon, L., & Seron, X. (2006). Non-algorithmic access to calendar information in a calendar calculator with autism. *Journal of Autism and Developmental Disorders*, 36(2), 239–247. <https://doi.org/10.1007/s10803-005-0059-9>
- Mottron, L., Ostrolenk, A., & Gagnon, D. (2021). In prototypical autism, the genetic ability to learn language is triggered by structured information, not only by exposure to oral language. *Genes*, 12(8), Article 1112. <https://doi.org/10.3390/genes12081112>
- Muniz, J., Jr., Muniz, P. C., Pinto, T. M., Schwartzman, J. S., & de Macedo, E. C. (2025). Etiopathogenic theories in savant syndrome: Scoping review. *Review Journal of Autism and Developmental Disorders*, 12(1), 8–22. <https://doi.org/10.1007/s40489-023-00372-8>
- Nation, K. (1999). Reading skills in hyperlexia: A developmental perspective. *Psychological Bulletin*, 125(3), 338–355. <https://doi.org/10.1037/0033-2909.125.3.338>
- National Reading Panel, National Institute of Child Health, & Human Development. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Reports of the subgroups*. National Institute of Child Health and Human Development, National Institutes of Health.
- Nelson, E. C., & Pribor, E. F. (1993). A calendar savant with autism and Tourette syndrome. Response to treatment and thoughts on the interrelationships of these conditions. *Annals of Clinical Psychiatry*, 5(2), 135–140. <https://doi.org/10.3109/10401239309148976>
- Norbury, C. F., Griffiths, H., & Nation, K. (2010). Sound before meaning: Word learning in autistic disorders. *Neuropsychologia*, 48(14), 4012–4019. <https://doi.org/10.1016/j.neuropsychologia.2010.10.015>
- Nurcombe, B., & Parker, N. (1964). The idiot savant. *Journal of the American Academy of Child Psychiatry*, 3(3), 469–487. [https://doi.org/10.1016/S0002-7138\(09\)60160-6](https://doi.org/10.1016/S0002-7138(09)60160-6)
- O'Connor, N., Cowan, R., & Samella, K. (2000). Calendrical calculation and intelligence. *Intelligence*, 28(1), 31–48. [https://doi.org/10.1016/S0160-2896\(99\)00028-8](https://doi.org/10.1016/S0160-2896(99)00028-8)
- O'Connor, N., & Hermelin, B. (1984). Idiot savant calendrical calculators: Maths or memory? *Psychological Medicine*, 14(4), 801–806. <https://doi.org/10.1017/S0033291700019772>
- O'Connor, N., & Hermelin, B. (1992). Do young calendrical calculators improve with age? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 33(5), 907–912. <https://doi.org/10.1111/j.1469-7610.1992.tb01964.x>
- Ogawa, R., Kagitani-Shimono, K., Matsuzaki, J., Tanigawa, J., Hanaie, R., Yamamoto, T., Tominaga, K., Hirata, M., Mohri, I., & Taniike, M. (2019). Abnormal cortical activation during silent reading in adolescents with autism spectrum disorder. *Brain & Development*, 41(3), 234–244. <https://doi.org/10.1016/j.braindev.2018.10.013>
- Olson, I. R., Berryhill, M. E., Drowos, D. B., Brown, L., & Chatterjee, A. (2010). A calendar savant with episodic memory impairments. *Neurocase*, 16(3), 208–218. <https://doi.org/10.1080/13554790903405701>
- Ostrolenk, A., Boisvert, M., & Mottron, L. (2025). What do autistic children who are interested in letters and numbers do with them? A qualitative study. *International Journal of Qualitative Studies on Health and Well-Being*, 20(1), Article 2500851. <https://doi.org/10.1080/17482631.2025.2500851>
- Ostrolenk, A., Courchesne, V., & Mottron, L. (2023). A longitudinal study on language acquisition in monozygotic twins concordant for autism and hyperlexia. *Brain and Cognition*, 173, Article 106099. <https://doi.org/10.1016/j.bandc.2023.106099>
- Ostrolenk, A., Forgeot d'Arc, B., Jelenic, P., Samson, F., & Mottron, L. (2017). Hyperlexia: Systematic review, neurocognitive modelling, and outcome. *Neuroscience and Biobehavioral Reviews*, 79, 134–149. <https://doi.org/10.1016/j.neubiorev.2017.04.029>

- Ostrolenk, A., Gagnon, D., Boisvert, M., Lemire, O., Dick, S. C., Côté, M. P., & Mottron, L. (2024). Enhanced interest in letters and numbers in autistic children. *Molecular Autism*, 15(1), Article 26. <https://doi.org/10.1186/s13229-024-00606-4>
- Ozonoff, S., & Iosif, A. M. (2019). Changing conceptualizations of regression: What prospective studies reveal about the onset of autism spectrum disorder. *Neuroscience and Biobehavioral Reviews*, 100, 296–304. <https://doi.org/10.1016/j.neubiorev.2019.03.012>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1), Article 89. <https://doi.org/10.1186/s13643-021-01626-4>
- Palmer, C. J., Lawson, R. P., & Hohwy, J. (2017). Bayesian approaches to autism: Towards volatility, action, and behavior. *Psychological Bulletin*, 143(5), 521–542. <https://doi.org/10.1037/bul0000097>
- Palo, J., & Kivalo, A. (1977). Calendar calculator with progressive mental deficiency. *Acta Paedopsychiatrica: International Journal of Child & Adolescent Psychiatry*, 42(6), 227–231.
- Park, H. O. (2023). Autism spectrum disorder and savant syndrome: A systematic literature review. *Journal of the Korean Academy of Child and Adolescent Psychiatry*, 34(2), 76–92. <https://doi.org/10.5765/jkacap.23.0003>
- Parker, E. S., Cahill, L., & McGaugh, J. L. (2006). A case of unusual autobiographical remembering. *Neurocase*, 12(1), 35–49. <https://doi.org/10.1080/13554790500473680>
- Patti, P. J. (1994). *Autistic savant calendar calculators* [Poster presentation]. Annual Meeting of the American Association on Mental Retardation, Boston, MA, United States.
- Patti, P. J., & Lupinetti, L. (1993). Brief report: Implications of hyperlexia in an autistic savant. *Journal of Autism and Developmental Disorders*, 23(2), 397–405. <https://doi.org/10.1007/BF01046228>
- Perruchet, P. (2005). Statistical approaches to language acquisition and the self-organizing consciousness: A reversal of perspective. *Psychological Research*, 69(5–6), 316–329. <https://doi.org/10.1007/s00426-004-0205-6>
- Peru, A. (2023). Calendar calculating or simply memory for dates? Evidence from a young female with autistic spectrum disorder. *Acta Neurologica Belgica*, 123(2), 721–722. <https://doi.org/10.1007/s13760-022-02035-7>
- Pesenti, M., Seron, X., Samson, D., & Duroux, B. (1999). Basic and exceptional calculation abilities in a calculating prodigy: A case study. *Mathematical Cognition*, 5(2), 97–148. <https://doi.org/10.1080/135467999387270>
- Pesenti, M., Zago, L., Crivello, F., Mellet, E., Samson, D., Duroux, B., Seron, X., Mazoyer, B., & Tzourio-Mazoyer, N. (2001). Mental calculation in a prodigy is sustained by right prefrontal and medial temporal areas. *Nature Neuroscience*, 4(1), 103–107. <https://doi.org/10.1038/82831>
- Pring, L., & Hermelin, B. (2002). Numbers and letters: Exploring an autistic savant's unpracticed ability. *Neurocase*, 8(4), 101–108. <https://doi.org/10.1076/neur.8.3.330.16193>
- Puente, A. E., Heller, S., & Sekely, A. (2016). Neuropsychological analysis of an idiot savant: A case study. *Applied Neuropsychology: Adult*, 23(6), 459–463. <https://doi.org/10.1080/23279095.2016.1159563>
- Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science*, 2(Suppl. 2), 31–74. <https://doi.org/10.1111/1529-1006.00004>
- Rimland, B. (1978). Savant capabilities of autistic children and their cognitive implications. In G. Serban (Ed.), *Cognitive defects in the development of mental illness* (pp. 43–65). Brunner/Mazel.
- Roberts, A. D. (1945). Case history of a so-called idiot-savant. *The Pedagogical Seminary and Journal of Genetic Psychology*, 66(2), 259–265. <https://doi.org/10.1080/08856559.1945.10533328>
- Rosen, A. M. (1981). Adult calendar calculators in a psychiatric OPD: A report of two cases and comparative analysis of abilities. *Journal of Autism and Developmental Disorders*, 11(3), 285–292. <https://doi.org/10.1007/BF01531511>
- Rubin, E. J., & Monaghan, S. (1965). Calendar calculation in a multiple-handicapped blind person. *American Journal of Mental Deficiency*, 70(3), 478–485.
- Rudziński, G., Pożarowska, K., Brzuszkiewicz, K., & Soroka, E. (2024). An outline of savant syndrome. *Psychiatria Polska*, 58(4), 681–691. <https://doi.org/10.12740/PP/OnlineFirst/157104>
- Rumsey, J. M. (1992). Neuropsychological studies of high-level autism. In E. Schopler & G. Mesibov (Eds.), *High-functioning individuals with autism* (pp. 41–64). Plenum. https://doi.org/10.1007/978-1-4899-2456-8_3
- Saffran, J. R., Newport, E. L., & Aslin, R. N. (1996). Word segmentation: The role of distributional cues. *Journal of Memory and Language*, 35(4), 606–621. <https://doi.org/10.1006/jmla.1996.0032>
- Saldaña, D., Carreiras, M., & Frith, U. (2009). Orthographic and phonological pathways in hyperlexic readers with Autism Spectrum Disorders. *Developmental Neuropsychology*, 34(3), 240–253. <https://doi.org/10.1080/87565640902805701>
- Saloviita, T., Ruusila, L., & Ruusila, U. (2000). Incidence of savant syndrome in Finland. *Perceptual and Motor Skills*, 91(1), 120–122. <https://doi.org/10.2466/pms.2000.91.1.120>
- Scheerer, M., Rothmann, E., & Goldstein, K. (1945). A case of "idiot savant": An experimental study of personality organization. *Psychological Monographs*, 58(4), i–63. <https://doi.org/10.1037/h0093584>
- Şevik, A. E., Kültür, E. Ç., Demirel, H., Oğuz, K. K., Akça, O., Ergün, E. L., & Demir, B. (2010). Asperger syndrome with highly exceptional calendar memory: A case report. *Türk Psikiyatri Dergisi*, 21(3), 249–255.
- Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 24(4), 613–620. <https://doi.org/10.1111/j.1469-7610.1983.tb00137.x>
- Shields-Wolfe, J., & Gallagher, P. A. (1992). Functional utilization of splinter skills for the employment of a young adult with autism. *Focus on Autistic Behavior*, 7(4), 1–16. <https://doi.org/10.1177/108835769200700401>
- Simner, J., & Hubbard, E. M. (2006). Variants of synesthesia interact in cognitive tasks: Evidence for implicit associations and late connectivity in cross-talk theories. *Neuroscience*, 143(3), 805–814. <https://doi.org/10.1016/j.neuroscience.2006.08.018>
- Smith, J., & Howe, M. J. (1985). An investigation of calendar-calculating skills in an "idiot savant". *International Journal of Rehabilitation Research*, 8(1), 77–78. <https://doi.org/10.1097/00004356-198503000-00009>
- Snowling, M., Bishop, D. V. M., & Stothard, S. E. (2000). Is preschool language impairment a risk factor for dyslexia in adolescence? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 41(5), 587–600. <https://doi.org/10.1111/1469-7610.00651>
- Spitz, H. H. (1995). Calendar calculating idiots savants and the smart unconscious. *New Ideas in Psychology*, 13(2), 167–182. [https://doi.org/10.1016/0732-118X\(95\)00003-Y](https://doi.org/10.1016/0732-118X(95)00003-Y)
- Stanley, J., Rabot, E., Reddy, S., Belilovsky, E., Mottron, L., & Bzdok, D. (2025). Large language models deconstruct the clinical intuition behind diagnosing autism. *Cell*, 188(8), 2235–2248.e10. <https://doi.org/10.1016/j.cell.2025.02.025>
- Taylor, M. J., van Leeuwen, T. M., Kuja-Halkola, R., Lundström, S., Larsson, H., Lichtenstein, P., Bölte, S., & Neufeld, J. (2023). Genetic and environmental architecture of synaesthesia and its association with the autism spectrum—A twin study. *Proceedings of the Royal Society B*, 290(2009), Article 20231888. <https://doi.org/10.1098/rspb.2023.1888>
- Thioux, M., Stark, D. E., Klaiman, C., & Schultz, R. T. (2006). The day of the week when you were born in 700 ms: Calendar computation in an Autistic savant. *Journal of Experimental Psychology: Human Perception and Performance*, 32(5), 1155–1168. <https://doi.org/10.1037/0096-1523.32.5.1155>

- Tomasello, M. (2020). The adaptive origins of uniquely human sociality. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1803), Article 20190493. <https://doi.org/10.1098/rstb.2019.0493>
- Treffert, D. (1989). *Extraordinary people*. Harper and Row.
- Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science*, 2(3), 67–70. <https://doi.org/10.1111/1467-8721.ep10770899>
- Ullman, M. T. (2001). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research*, 30(1), 37–69. <https://doi.org/10.1023/A:1005204207369>
- Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92(1–2), 231–270. <https://doi.org/10.1016/j.cognition.2003.10.008>
- van Leeuwen, T. M., Wilsson, L., Normann, H. N., Dingemanse, M., Bölte, S., & Neufeld, J. (2020). *Perceptual processing links autism and synesthesia: A twin study*. <https://doi.org/10.31234/osf.io/b2mvg>
- Vulchanova, M., Talcott, J. B., Vulchanov, V., Stankova, M., & Eshuis, H. (2012). Morphology in autism spectrum disorders: Local processing bias and language. *Cognitive Neuropsychology*, 29(7–8), 584–600. <https://doi.org/10.1080/02643294.2012.762350>
- Vulchanova, M., Vulchanov, V., & Allen, M. (2023). Word learning in ASD: The sensorimotor, the perceptual and the symbolic. *Journal of Cultural Cognitive Science*, 7(1), 9–22. <https://doi.org/10.1007/s41809-022-00117-9>
- Wallace, G. L. (2006). *Cognitive mechanisms underlying savant skills in autism* [Doctoral dissertation]. University of London.
- Wallace, G. L., Happé, F., & Giedd, J. N. (2009). A case study of a multiply talented savant with an autism spectrum disorder: Neuropsychological functioning and brain morphometry. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1425–1432. <https://doi.org/10.1098/rstb.2008.0330>
- Waterhouse, L. Y. N. N. (2013). *Rethinking autism: Variation and complexity* (1st ed.). Academic Press.
- Waxman, S. R., & Lidz, J. (2006). Early word learning. In D. Kuhn & R. Siegler (Eds.), *Handbook of child psychology* (6th ed., pp. 299–335). Wiley.
- Winter, B., & Reber, A. S. (1994). Implicit learning and natural language acquisition. In N. Ellis (Ed.), *Implicit and explicit learning of languages* (pp. 115–146). Academic Press.
- Young, R. L. (1995). *Savant syndrome: Processes underlying extraordinary abilities* [Doctoral dissertation]. University of Adelaide, Department of Psychology.
- Young, R. L., & Nettelbeck, T. (1994). The “intelligence” of calendrical calculators. *American Journal on Mental Retardation*, 99(2), 186–200.
- Zhukova, M. A., Talantseva, O. I., An, I., & Grigorenko, E. L. (2023). Brief report: Unexpected bilingualism: A case of a Russian child with ASD. *Journal of Autism and Developmental Disorders*, 53(5), 2153–2160. <https://doi.org/10.1007/s10803-021-05161-y>
- Ziegler, E., Edelsbrunner, P. A., & Stern, E. (2018). The relative merits of explicit and implicit learning of contrasted algebra principles. *Educational Psychology Review*, 30(2), 531–558. <https://doi.org/10.1007/s10648-017-9424-4>

Appendix

Calendar Theory

The calendar system is universally used to organize long-term time representation. There is a multitude of calendar types, depending on culture or religious beliefs, which can be based on the lunar and/or solar periodicities. Prior to the Gregorian calendar, Europe mainly used the Julian calendar, introduced by Julius Caesar in 45 B.C. (Fortunado, 2014). The Julian calendar had an excess of 11 min per year over the tropical year, which corresponds to the time it takes for the Earth to complete one orbit around the Sun, relative to the cycle of the seasons, resulting in a gradual seasonal shift. This means that the dates of the solstices and equinoxes (and hence the seasons) would gradually drift away from their intended positions on the calendar. Without periodic correction, summer would eventually begin in mid-July instead of late June, for example. In 1582, Pope Gregory XIII and the mathematician and astronomer Christophe Clavius introduced the Gregorian calendar to retrospectively realign the dates of the equinoxes with the solar cycle. Ten days were consecutively removed from the Julian calendar by having October 15, 1582, immediately following October 4, 1582. To avoid a similar shift in the future, this reform also introduced “leap” years, adding a day to years divisible by four but excluding those divisible by 100, unless they were divisible by 400. The calendar reform was quickly adopted in Catholic states, but its adoption in Protestant and Orthodox states took place at different times to become now the standard calendar used in most countries. It is the international civil calendar of reference for most daily activities, integrating some religious and

traditional calendars (e.g., Easter) for specific events. It follows a consistent structure: A week consists of 7 days, and a year comprises 12 months spanning from 28 to 31 days. Leap years, occurring every 4 years, extend to 366 days with the addition of February 29, while nonleap years maintain 365 days. The calendar repeats itself every 28 years and every 400 years. Considering leap years, each 6-year interval includes a single leap year, ensuring the calendar’s structure remains unchanged. Similarly, within every 11-year interval, incorporating three leap years, the calendar structure remains consistent. Because the 11-year interval consistently incorporates the same number of leap years, the pattern of how dates align with weekdays remains stable, repeating every 11 years. The Chinese calendar, still used in China and some Asian countries in combination with the Gregorian calendar, follows the phases of the moon so that each month begins with the new moon. In addition, the 24-lunar period solar cycle is also considered, allowing the calendar to follow the course of the seasons. A thorough knowledge of the lunar cycle is therefore necessary to master this calendar, as there are no regularities such as those found, for example, in the Gregorian calendar.

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