The Impact of Synaesthesia on Inclusive Teaching and Learning: A Systematic Literature Review

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ORIGINAL ARTICLE

The impact of Synaesthesia on inclusive teaching and learning: A systematic literature review

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Abstract

Synaesthesia is a neurodevelopmental phenomenon involving consistent, involuntary cross-modal sensory experiences. Though well-documented in cognitive neuroscience, its implications for educational practice remain underexplored. This systematic narrative literature review investigates how synaesthesia may impact children's learning and inform inclusive classroom pedagogy. Using Xiao and Watson's (2019) review typology and the PRISMA framework for study selection, 23 studies were synthesised across four key themes: (1) cognitive and perceptual advantages, (2) educational impacts and learning strategies, (3) developmental trajectory and (4) broader cognitive and personality profiles. Findings indicate that synaesthetes often display enhanced memory, associative learning and creativity, traits that could be leveraged in classroom contexts. However, challenges arise when educational materials conflict with individual perceptual mappings. Despite these findings, current pedagogical guidance and intervention strategies for synaesthetic learners are scarce. The review underscores a need for greater professional awareness and tailored educational approaches aligned with the neurodiversity framework. It concludes that synaesthesia, while often overlooked, holds significant potential for informing strength-based and inclusive education.

KEYWORDS
cognitive learning, inclusive education, neurodiversity, strength-based approaches, synaesthesia

Key points

- Synaesthesia can confer advantages in memory, associative learning and creativity. These benefits translate to classrooms when materials align with a learner's mappings; incongruent colour-coding can hinder performance.
- Practical supports: personalise colour-based tools, use multimodal teaching and raise teacher awareness. Evidence for classroom interventions is promising but sparse.
- Development: synaesthesia typically emerges in childhood, shaped by environment and predisposition. Most studies use adults; more child-focused, consistency-verified research is needed.
- Research agenda: test neurodiversity-informed, strength-based pedagogies; evaluate tailored tools at scale; examine subtype (e.g. projector/associator) differences; and track impacts on attainment, engagement and metacognition.

INTRODUCTION

The global trend towards inclusivity in education is evolving, positively influencing pedagogical practices at the mainstream classroom level (Ydo, 2020). The requirement to provide instructional adaptations to accommodate diverse learning needs and cognitive presentations is expanding, as demonstrated in supra-national educational policy directions (See: OECD, 2020, 2022). Conditions that have traditionally received less attention are now the focus. This growing complexity is further shaped by the convergence of the neurodiversity framework with strength-based assessment and practice (Fung & Doyle, 2021; Sewell & Park, 2021). The developmental phenomenon of synaesthesia exists at this nexus. It highlights the need for more research on lesser-known neurodiversity to strengthen their role in inclusive education and evidence-based practice. This paper presents a systematic literature review of synaesthesia research to achieve this aim.

Synaesthesia is a neurological-developmental phenomenon characterised by involuntary and consistent cross-modal sensory experiences, in which stimulation of one sensory or cognitive pathway leads to automatic experiences in another (Simner, 2012). Individuals with synaesthesia, known as synaesthetes, experience a wide range of perceptual variations (Simner, 2012). The most commonly recognised form is grapheme-colour synaesthesia, in which visual stimuli such as words or numbers trigger the involuntary inner-perception of colours. However, it is more accurate to say that this is the most researched form, making it the best understood and most frequently assessed. The prevalence of synaesthesia is estimated to be around 4% of the population (Simner et al., 2006), though it varies in expression and intensity across individuals (Watson et al., 2017).

Day (2025) provides an updated list of all known variants of synaesthesia. To outline the most prominent in research, Grapheme-based forms include grapheme–colour synaesthesia, where letters or numbers reliably evoke specific colours; ordinal–linguistic personification (OLP), in which sequences such as numbers, letters or weekdays have stable personalities or genders; and number–form synaesthesia, where numbers are mapped onto consistent spatial layouts. Sound-based forms include chromesthesia, where sounds or music elicit colours; timbre–shape synaesthesia, in which different instrumental timbres trigger distinct shapes or textures; pitch–space synaesthesia, where musical notes are perceived at fixed locations in space; and linguistic–colour synaesthesia, where spoken words or phonemes evoke colours. A tactile-based form is mirror–touch synaesthesia, where seeing another person being touched produces a corresponding tactile sensation on one's own body.

The neurodiversity framework views variations in neuro-cognitive and learning differences as natural and valuable aspects of human diversity, rather than as deficits or disorders (Fung & Doyle, 2021). It emphasises the importance of recognising and accommodating diverse cognitive, sensory and social processing styles, advocating for strength-based approaches that support individual needs while challenging normative standards of functioning (Fung & Doyle, 2021; Sewell & Park, 2021). Synaesthesia, framed within the neurodiversity paradigm, is recognised as a natural human variation. Synaesthesia may offer cognitive and creative advantages that enhance learning and problem-solving (Newell & Mitchell, 2016). Furthermore, synaesthesia is comorbid with autism, which is a neurodivergent condition that has presentations of cognitive variations, such as atypical sensory processing and heightened perception (Simner et al., 2006). It has been suggested that these cognitive mechanisms may explain why synaesthesia is more prevalent in neuro-developmental conditions such as autism, occurring in 20 percent of this population (Van Leeuwen et al., 2019).

To date, synaesthesia has not garnered the same level of recognition or research focus as other neurodiversities. This is particularly so for research that seeks to consider implications for applied pedagogical practice and inclusive educational adaptations. It is likely it has not had such focus because it does not have comparable adverse impact to other neurodiverse profiles. As a likely consequence of its lower profile, limited professional awareness of synaesthesia and its potential implications for teaching and learning is reflected in its absence from initial teacher training programmes and the scarcity of dedicated educational resources.

To address this, the reported systematic literature review was undertaken to synthesise existing knowledge on the impact of synaesthesia on learning, and related teaching implications; an important step towards raising awareness and informing classroom practice. Research objectives were:

> RO1: Develop an understanding of how synaesthesia and subtypes potentially impact children's learning.
>
> RO2: Evaluate current educational practice for supporting the inclusion and learning of pupils with synaesthesia.

METHOD

The specific subtype of systematic literature review was determined using Xiao and Watson's (2019) typologies. It was concluded that the review constituted a narrative review, aiming to describe 'the state of the literature as it pertains to the research questions' (Xiao & Watson, 2019, p. 95). Xiao and Watson's (2019) framework for the stages of a literature review was then adopted to structure the

approach, as well as drawing on Moher et al. (2015) to develop protocol, as follows:

1. Formulate the problem
2. Develop and validate the review protocol
3. Search the literature
4. Screen for inclusion
5. Assess quality
6. Extracting data
7. Analysing and synthesising data
8. Report findings

1. Formulate the problem

In formulating the research problem, the team encountered a common issue: selecting research questions that were too broad (Xiao & Watson, 2019, p. 103). At this initial stage, the research questions were refined to exclude the original intention to include a focus on social–emotional development as well as learning, resulting in the following:

- RQ1: What is the potential impact of synaesthesia on children's learning?
- RQ2: What current classroom pedagogy is practiced supporting the inclusion and attainment of learners with synaesthesia, and what does it purport?
- RQ3: What specific, targeted educational interventions exist for supporting the attainment of learners with synaesthesia?
- RQ4: Are any of these three domains of intervention/support differentiated by synaesthesia subtype and does this have a positive impact on effectiveness?

2. Develop and validate review protocol

Review protocol was developed and pre-published at the International Database of Educational Systematic Reviews (IDESR ID: IDESR000138). While applying the broad frameworks of Xiao and Watson (2019) and Moher et al. (2015) the protocol specifically applied:

a. Prisma approach to recording database search, screening and inclusion (Page et al., 2021);
b. Gough (2007) Weight of Evidence framework for appraising quality and relevance of evidence;
c. Popay et al. (2006) techniques for developing the preliminary synthesis of textual descriptions of studies, tabulation, and translating data through;
d. Thematic analysis of tabulated data and textual descriptions (Braun et al., 2023). The further relevance of each element of the protocol is detailed in the following stages.

3. Search the literature

Figure 1 presents the PRISMA flow diagram. Databases used were EBSCO, British Education Index, Academic

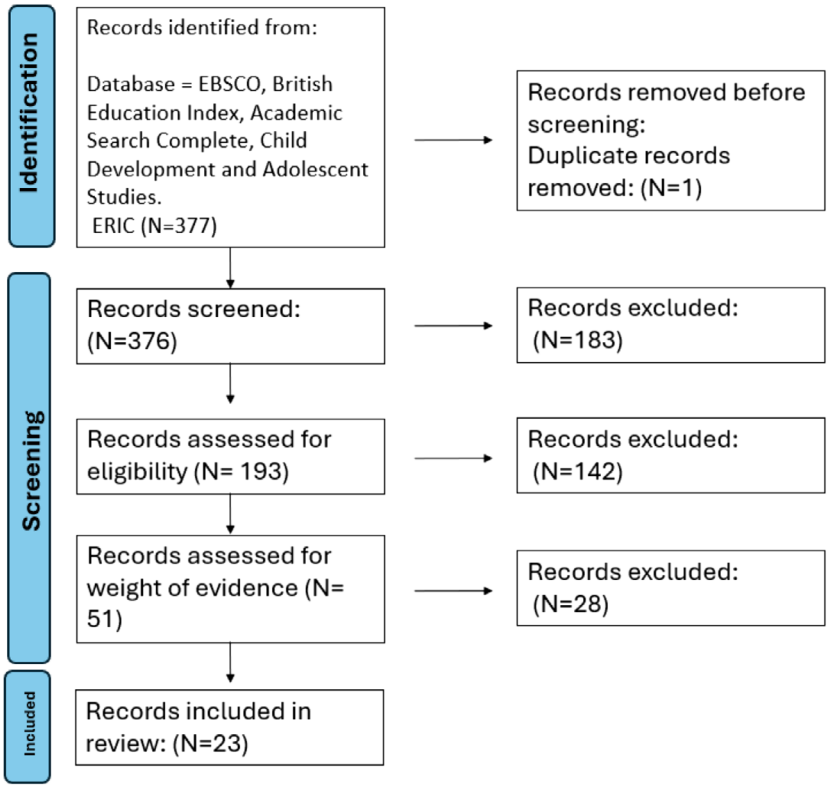

FIGURE 1 PRISMA.

Search Complete and Child Development and Adolescent Studies. To ensure the database selection did not bias results towards education-only literature, we conducted a targeted validation search in PsycINFO/Web of Science using the core search string. Titles and abstracts from the first 50 results were screened, identifying no new studies meeting inclusion criteria. This suggests substantial overlap across indexing platforms and supports the adequacy of the original database selection, which already captured psychology-domain sources through Academic Search Complete and citation chaining.

Search terms employed boolean logic, with primary search terms of "synaesthesia" and "synaesthetes" searched systematically with the following 'AND' secondary terms of "education", "school*", "learning", "teaching", "classroom", "education policy", "pedagogy", "learning intervention*", and "classroom intervention*". In addition, further papers were identified by using finding functions such as the 'you may enjoy these papers' sidebar (or similar) and 'as cited by' to further expand initial search.

Search terms combined controlled vocabulary and free-text synonyms. Although the initial free-text seeds listed the UK spelling ('synaesthesia/synaesthetes'), eligibility was not restricted by geography or spelling. Records using the US variant were captured through database subject headings where available, and through backward and forward citation chasing from core reviews and empirical studies, several of which use the US spelling. Because the initial free-text seeds used the UK spelling, there remains a small risk that isolated US-spelled records not linked via subject headings or citation networks were missed; this risk was mitigated through additional citation chasing of key reviews and studies using the US spelling, yielding no additional counts.

4. Screen for inclusion

Screening for inclusion was a multi-step process. The first screening was based on titles and meta-data and was completed by the project research assistant. Inclusion criteria were as follows:

1. Published in the period 2000 to 2024 for meta-analyses and the period 2014 to 2024 for primary studies;
2. Articles published in English;
3. Studies published in journal articles, books, conference papers and proceedings, dissertations and theses; and working papers;
4. Quantitative, qualitative and mixed methods empirical studies and reviews;
5. Studies reviewed as relevant to ROs and RQs via review protocol,

Exclusion criteria were as follows:

1. Articles not available in English;
2. Opinion pieces;
3. Published pre-2000 for meta-analyses and pre-2014 for primary studies.

The second screening was based on abstracts, with all three members of the research team independently assessing relevance to the research questions. Triangulation and consensus were achieved during a team meeting, where full agreement on a paper's inclusion at this stage led to iterative screening and final selection.

5. Assess quality

At this stage of the protocol, 51 papers were assessed. Each member of the team individually completed a first full reading of each paper. During a research team meeting, Gough's (2007) Weight of Evidence framework was applied to appraise the quality of each paper through group discussion. This approach allowed for a structured assessment of each study's contribution to the review by considering both its methodological robustness and its relevance to our research questions. By methodological robustness, we mean the extent to which a study uses an appropriate and transparent design, sampling strategy, measures and analytic procedures, demonstrates reliability and validity and manages potential biases so that its findings are credible and reproducible.

Weight of Evidence A (WoE A) assessed each study's coherence and integrity as a piece of research, using widely accepted quality criteria. This non-review-specific judgement rated studies from 1 to 10 based on methodological rigour, transparency and reliability. Weight of Evidence B (WoE B) evaluated the appropriateness of the study's methodology for addressing our research questions. While experimental studies may offer strong causal insights, they may be less suited to exploring complex processes. Studies were rated 1 to 10 based on their methodological relevance to the review. Weight of Evidence C (WoE C) assessed the topical relevance of each study, considering how well its focus, sample and data collection aligned with our research questions. Ethical appropriateness and generalisability were also considered, with studies rated 1 to 10 for their relevance to the review's aims.

Verification of synaesthesia via a recognised consistency test (e.g. repeat-measures inducer–concurrent matching tasks) was also noted where reported in papers and considered within the Weight of Evidence judgements (A–C). Studies that did not report consistency verification were not excluded a priori but were down-weighted on WoE A and/or B and interpreted cautiously in synthesis.

Combining these three dimensions ensured a rigorous and transparent approach to evaluating the contribution of each study, balancing considerations of research quality with its applicability. Papers that received a total weight of evidence score D of 24/30 and above were included in the final iteration of included papers, with 28 excluded at this stage. The Weight of Evidence meta-data are available on request from the corresponding author.

TABLE 1 Included papers.

Author	Year	Type	Adult or child sample
Bankieris & Aslin	2016	Experimental study	Adult
Bankieris & Aslin	2017	Experiment study	Adult
Berger, Harris, Whittingham, Terpening & Watson	2021	Experiment study	Adult
Chun & Hupé	2016	Experiment study	Adult
Elkoshi	2018	Experiment study	Child
Forest, Lichtenfeld, Alvarez & Finn	2019	Experiment study	Adult
Green & Goswami	2008	Experiment study	Child
Hale, Thompson, Morgan, Cappelletti & Cohen Kadosh	2014	Experiment study	Adult
Basirat & Hupé	2020	Exploratory analysis	Child
Rothen & Meier	2009	Experiment study	Adult
Rothen & Meier	2010	Experiment study	Adult
Rothen, Scott, Mealor, Coolbear, Burckhardt & Ward	2013	Experiment study	Adult
Simner & Bain	2018	Experiment study	Child
Smees, Hughes, Carmichael & Simner	2019	Longitudinal study	Child
Ward	2019	Systematic review	Adult
Watson, Blair, Kozik, Akins & Enns	2012	Experiment study	Adult
Watson, Akins, Spiker, Crawford & Enns	2014	Critical review	Child
Watson, Chromý, Crawford, Eagleman, Enns & Akins	2017	Experiment study	Adult
Williams, Gumtau & Mackness	2015	Case studies.	Child
Pritchard, Rothen, Coolbear & Ward	2013	Experiment study	Adult
Rothen, Berry, Seth, Oligschläger & Ward	2020	Experiment study	Adult
Simner & Bain	2013	Experiment study	Child
Harkness, Noblitt & Giesbers	2023	Qualitative interviews	Adult

6. Extracting data

Table 1 presents final included papers and key information. Each member of the team individually re-read included papers and created a textual description of each paper, each one being tabulated. Summaries of RQ/aims, methodology/methods, key findings were also extracted and tabulated along with year of publication, sample (adult/child), and sample size (Popay et al., 2006) (tabulation is available as metadata request from corresponding author).

7. Analysing and synthesising data

Applying reflexive thematic analysis (Braun et al., 2023), initial codes were generated for each paper via tabulated data. From these, axial codes were developed and summarised into refined categories across papers, with papers then retrospectively mapped back onto the refined categories. Axial codes and categories were related into initial themes, which were then iterated into final themes and sub-themes. A textual summary was written for each theme to aid final mapping of papers onto themes and sub-themes and to aid the reporting of themes.

FINDINGS

Theme 1: Specific cognitive mechanisms and perceptual advantages in synaesthesia

Theme 1 highlights a trend in the literature that synesthetes often demonstrate perceptual advantages and superior performance in specific cognitive mechanisms during cognitive assessment tasks. These advantages are believed to be directly linked to their synesthetic experiences. The sub-themes explore how synesthetes implicitly leverage their unique perceptual associations to process sensory information differently from non-synesthetes in areas such as memory, associative learning, colour perception, and word segmentation. Additionally, they examine how synesthetes explicitly employ these perceptual differences to enhance cognitive processing.

Synesthetes demonstrate enhanced memory and related learning abilities (sub-theme 1A), leveraging perceptual associations to reinforce cognitive processing. Research by Bankieris and Aslin (2016, 2017) shows that synesthetes exhibit faster explicit associative learning and retain implicit learning effects longer than non-synesthetes, suggesting a fundamental difference in memory encoding. Similarly, Rothen and Meier (2009,

2010), Rothen et al. (2013, 2020) and Forest et al. (2019) provide consistent evidence that synesthetes outperform controls in working memory and associative tasks, particularly when colour-based cues are involved, reinforcing the notion that synesthetic experiences enhance cognitive retention and retrieval.

Synesthetes also demonstrate perceptual processing advantages (sub-theme 1B), particularly in colour perception, spatial cognition and multi-sensory integration. Berger et al. (2021) found that synesthetes performed better on colour-coded numerical tasks when the colours aligned with their synesthetic mappings, highlighting their reliance on perceptual associations. Similarly, Green and Goswami (2008) identified enhanced number-space associations, with synesthetes demonstrating superior spatial memory for numerical-related tasks. Chun and Hupé (2016) further suggested that synesthetes exhibit greater cognitive flexibility and creative problem-solving abilities, likely due to their heightened perceptual integration. Neuroimaging research by Hale et al. (2014) supports these behavioural findings, revealing increased connectivity between colour-processing and language areas of the brain, which may underlie synesthetes' enhanced sensory discrimination and integration as a perceptual processing advantage.

Synesthetes seem to employ explicit cognitive strategies that enhance memory and learning (sub-theme 1C) by leveraging their processing and memory advantages. Research by Pritchard et al. (2013) and Rothen et al. (2013, 2020) demonstrates that synesthetes engage in dual coding and cross-modal integration, using their synesthetic perceptions to reinforce recall and understanding. Dual coding is a cognitive theory that suggests information is better retained and recalled when it is processed through multiple sensory modalities, such as combining visual and verbal representations. Bankieris and Aslin (2016, 2017) further suggest that these strategies function as mnemonic aids, with synesthetes relying on their perceptual mappings to improve learning.

In summary, experimental research in Theme 1 demonstrates that synesthetes likely exhibit perceptual advantages and related enhanced cognitive performance, directly linked to their synesthetic experiences. These advantages manifest in three key areas: memory and associative learning, perceptual processing and strategic cognitive approaches.

Theme 2: Educational impact and learning strategies in synaesthesia

Theme 2 explores research examining the impact of synaesthesia on learning experiences and educational outcomes. It is closely linked to Theme 1, as the cognitive and perceptual advantages associated with synaesthesia are considered within the context of formal education. However, it also addresses challenges such as difficulties in acquiring and retaining curriculum content due to incongruent sensory experiences or perceptual overload. As such, this theme focuses on strategies educators can use to support synesthetic students, including multi-sensory approaches and individualised accommodations.

While synesthetes can benefit from their perceptual associations (Theme 1), they may also face challenges when sensory inputs are incongruent (sub-themes 2A/2B). Research by Berger et al. (2021) and Watson et al. (2012, 2014) highlights that synesthetic students often use colour-based mnemonic aids to enhance recall and comprehension, integrating their associations into learning strategies. However, these advantages can become obstacles when educational materials conflict with their sensory mappings, as shown in Berger et al.'s (2021) findings on decreased performance with incongruent colour-coded stimuli. Watson et al. (2012, 2014) and Williams et al. (2015) further indicate that a lack of awareness among educators can lead to teaching methods that unintentionally disrupt synesthetic students' learning. Similarly, Smees et al. (2019) found that while multi-sensory interventions can be beneficial, conventional teaching approaches often fail to accommodate synesthetic processing, potentially leading to sensory overload and difficulties in acquiring new information.

However, individualised multi-sensory and cross-modal learning strategies can significantly enhance engagement and understanding for synesthetic learners by aligning with their perceptual experiences (sub-theme 2A). Research by Smees et al. (2019) and Harkness et al. (2023) demonstrates that tailoring instruction to a synesthete's sensory strengths, such as integrating auditory, visual, and tactile cues, improves comprehension and retention. Berger et al. (2021) further supports this by showing that colour-coded numerical tools enhanced learning when they matched a student's synesthetic associations, whereas incongruent sensory inputs hindered performance. These findings suggest that structured multi-sensory learning approaches can optimise educational experiences for synesthetic students.

In summary, synaesthesia has the potential to influence school-based learning in both beneficial and challenging ways, requiring tailored educational strategies to support students effectively. While synesthetes often use perceptual associations to enhance memory and learning, they may struggle with incongruent sensory inputs or perceptual overload (Berger et al., 2021; Watson et al., 2012, 2014).

Theme 3: Developmental trajectory and onset of synaesthesia

Theme 3 examines the developmental trajectory of synaesthesia as a childhood phenomenon shaped by environmental influences, learning contexts, and genetic

predispositions. Notably, it is hypothesised that diverse early cognitive profiles may play a role in its onset and maturation.

Synesthetic associations often emerge in early childhood, fluctuating before stabilising as cognitive development progresses (sub-theme 3A). Research by Simner and Bain (2018) suggests that advanced memory, pattern recognition, and structured learning environments (e.g., multilingualism, music exposure) contribute to the formation and consolidation of synesthetic traits. Watson et al. (2014) further found that some children experience temporary synesthetic traits, while others develop stable associations linked to strong visual memory and creativity. These findings indicate that both cognitive abilities and environmental stimuli play a crucial role in early development and stabilisation.

Synaesthesia may also develop as an adaptive response to early learning environments (sub-theme 3B). Basirat and Hupé (2020) provided neuroimaging evidence that early sensory experiences influence neural connectivity, reinforcing the idea that statistical learning processes contribute to the emergence of synaesthesia. Watson et al. (2014) further indicated that synesthetic children naturally integrate cross-modal associations into learning, particularly in visual memory and pattern recognition tasks, highlighting a reciprocal relationship between learning demands and synesthetic processing. These adaptive responses are predisposed with a suggested hereditary component in heightened neural connectivity in sensory integration areas (Basirat & Hupé, 2020; Simner & Bain, 2018) (sub-theme 3C).

In summary, synaesthesia emerges in early childhood, influenced by a combination of cognitive abilities, environmental factors, and genetic predisposition. Research suggests that memory, pattern recognition, and structured learning environments contribute to its development and stabilisation (Simner & Bain, 2013, 2018; Watson et al., 2014). Synesthetic experiences may also serve as adaptive learning responses, shaped by early educational exposure (Basirat & Hupé, 2020; Simner & Bain, 2018).

Theme 4: Broader cognitive profile and individual differences in synaesthetes

The final theme clusters and summarises research, which has outlined broader cognitive profile differences in synaesthetes including creativity, cognitive flexibility and problem-solving abilities. These emerge from how synaesthesia experiences developmentally interact with personality traits and broader cognitive functions.

Synesthetes often demonstrate heightened creativity, cognitive flexibility and divergent thinking, likely due to their ability to integrate cross-modal sensory information (sub-theme 4A). Research by Chun and Hupé (2016) and Ward (2019) shows that synesthetes outperform non-synesthetes in cognitive flexibility tasks and problem-solving, suggesting that their unique perceptual experiences enhance adaptability. Simner and Bain (2018) and Watson et al. (2017) further link higher synesthetic intensity to increased creativity and openness to experience, while Elkoshi (2018) found that synesthetic children display stronger cross-modal associations that influence artistic expression. These findings indicate that synaesthesia may contribute to broader cognitive strengths such as creativity, flexible thinking and problem-solving.

Synesthetes often exhibit distinct personality traits, such as openness to experience, absorption and heightened sensory sensitivity, which influence their cognitive styles and learning preferences (sub-theme 4B). Simner and Bain (2018) and Watson et al. (2017) found that synesthetes score higher in openness and emotional sensitivity. Ward (2019) and Hale et al. (2014) further demonstrated that synesthetic intensity of personality correlates with deep cognitive engagement and absorption, suggesting that personality-driven attentional styles may bi-directionally shape synesthetic experiences. Williams et al. (2015) highlighted how these traits influence learning preferences, with synesthetic students benefiting from sensory-rich and immersive educational approaches. These findings indicate that synaesthesia is not only a perceptual phenomenon but also likely developmentally tied to broader cognitive and personality-based differences.

In summary, research suggests that synesthetes exhibit distinct broader cognitive profiles, characterised by heightened creativity, cognitive flexibility and problem-solving abilities. These cognitive strengths appear to stem from their cross-modal sensory integration, which enhances adaptability and divergent thinking (Chun & Hupé, 2016; Ward, 2019). Studies also highlight key personality traits associated with synaesthesia, such as openness to experience, absorption, and heightened sensory sensitivity, which shape cognitive styles and learning preferences (Simner & Bain, 2018; Watson et al., 2017). These findings indicate that synaesthesia extends beyond perception and basic cognitive functioning, interacting with broader cognitive and personality-based differences that further shape individual learning (Figure 2).

DISCUSSION

The purpose of this systematic narrative literature review was to develop an understanding of how synaesthesia (including its subtypes) may impact children's learning. The review explored whether synaesthesia influences both benefits and challenges for learning, wishing to gain direction for teaching in educational contexts. A secondary objective was to evaluate current educational practices to determine how pupils with synaesthesia are supported and/or have their learning enhanced.

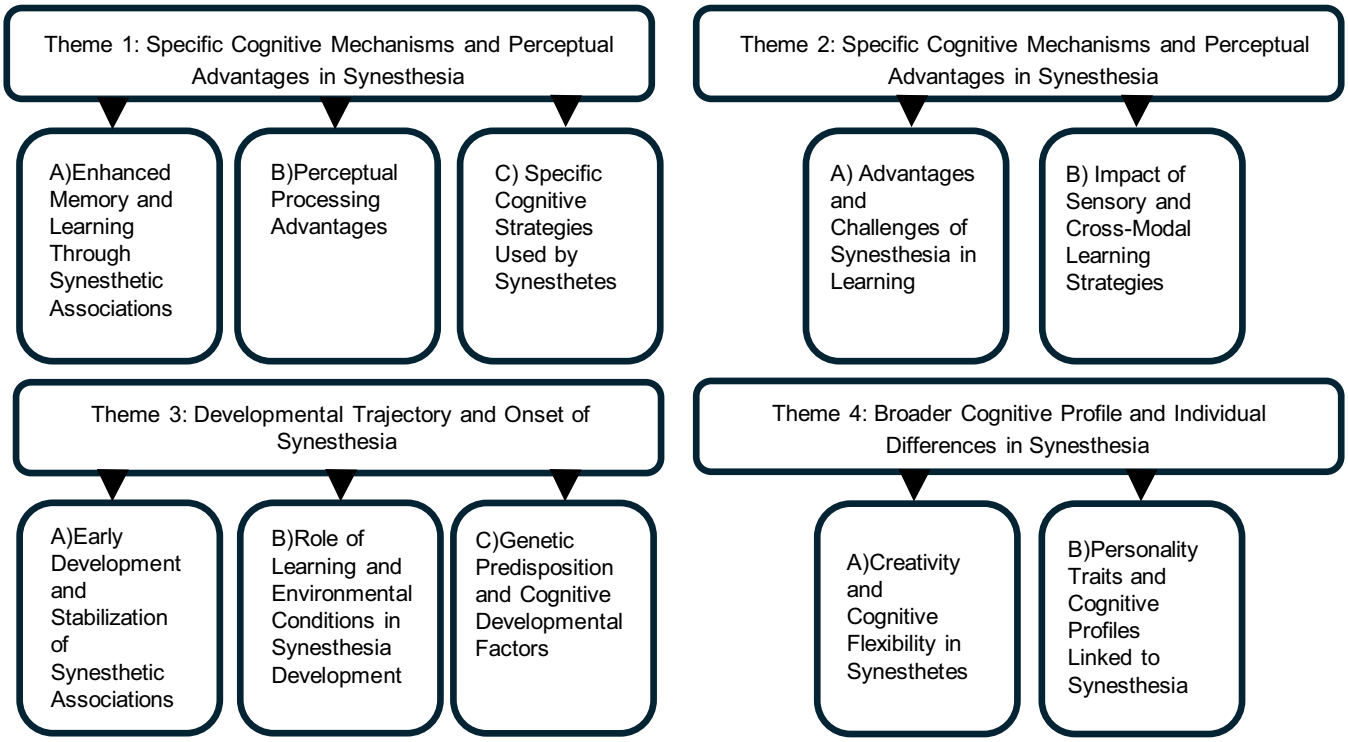

FIGURE 2 Thematic diagram.

Impact on learning

The findings provided a satisfactory response to RQ1. Synaesthetes appear to implicitly leverage their heightened perceptual processing to enhance associative learning and related working memory (T1; 1A, 1B). They also seem to employ dual-coding and cross-modal integration as information-processing strategies (T1, 1C). Given that perceptual processing and working memory are primary cognitive skills known to support learning acquisition, retention and subsequent attainment, and that cross-modal retrieval and dual-coding facilitate deep learning, the overall picture suggests that synaesthetic experiences can have a positive impact on learning. However, it is a more nuanced picture, as these benefits are only conferred if sensory inputs inherent in learning materials are congruent with synaesthetic representations. Incongruent colour-coded stimuli have the potential to inhibit learning (T2, 2A, 2B).

Still, beyond the level of primary cognitive functions, synaesthesia continues to confer benefits that would seemingly generalise to school education contexts. Synesthetes demonstrate superior skill levels in problem-solving tasks, flexible thinking and creativity (T4, 4A). This enhanced adaptability has the potential to inform metacognitive skills, particularly awareness of one's thinking processes and the deliberate use of attentional resources for planning and task-switching. Such metacognitive processes and interrelated executive functions have long been posited as central to deeper learning and the broader educational goals of self-actualisation and efficacy, extending beyond mere knowledge acquisition and skill development (see: Zimmerman, 2002). Similarly, the common personality traits observed in synaesthetes, such as openness and absorption, have been shown to facilitate deep task engagement, creating opportunities for sustained and intense cognitive processing. Together, it seems likely that synaesthesia may positively enhance learning through influence on the development of traits conducive to sustained task attention and meaningful engagement.

On balance, the current review suggests that synaesthetic experiences are more likely to enhance learning rather than act as a barrier. However, this advantage depends on both the individual child's awareness of their synaesthesia and educators' ability to implement appropriate adaptations. Despite the potential for enriched learning and more inclusive practice, the review highlights a comparative lack of research on pedagogy and intervention in this area. This is discussed below with regard to research questions 2 and 3.

Educational and instructional implications

It cannot be stated with confidence that the findings provided sufficient answers to RQs 2 and 3. There is a notable scarcity of research examining classroom pedagogy and inclusive adaptations for synaesthetic learners. Similarly, there is limited evidence on targeted learning interventions and their associated effectiveness. The most relevant study in this area is Berger et al.'s (2021)

project, which explored the use of a tailored calculator allowing number colours to be personalised to align with an individual's grapheme-colour experiences. Williams et al. (2015) also present two case studies in which teachers deliberately adapted their pedagogy to provide cross-modal learning experiences for a 5-year-old and a 9-year-old with synaesthesia. Overall, the literature review highlights a significant gap in research, underscoring the need for further exploration in this area.

However, all four findings highlight key starting points for developing pedagogical adaptations and interventions to support synaesthetic learners. Personalised learning tools, such as colour-customisable calculators and multi-sensory resources, could enhance engagement and comprehension. Cross-modal teaching strategies, including the use of colour-coded numbers, music and movement, may help align instruction with synaesthetic experiences. Raising teacher awareness through professional development and resource provision is essential, alongside classroom adaptations that support sensory integration, such as colour-coded materials and multimodal assessments. Targeted learning interventions, such as colour-based memory techniques, could further enhance literacy and numeracy skills. Expanding case study research and empirical studies on these approaches is necessary to establish evidence-based best practices and inform inclusive pedagogy.

As synaesthesia is recognised as a developmental phenomenon and an environmental adaptation emerging from interactions with learning challenges (T3), there is clear scope for future research to explore its potential benefits for all learners, not just those with established synaesthesia. Enhancing associative learning through colour pairings or other sensory associations could present an innovative approach to strengthening working memory in classroom settings. Given that synaesthesia is positioned within the neurodiversity framework, such an approach could serve as an inclusive design strategy, benefiting a wide range of learners with diverse cognitive profiles rather than functioning as a retrofitted intervention for individuals. However, substantial further research is needed to establish the efficacy and practical application of such an idea.

Limitations

The decision to discuss findings related to question four within the limitations section stems from the review's discovery that existing literature predominantly focusses on grapheme-colour synaesthesia. Consequently, it is not yet possible to determine whether pedagogical strategies or targeted interventions should be tailored to different subtypes, nor how such differentiation might impact effectiveness. This represents both a limitation of the current review, requiring findings to be interpreted primarily within the context of grapheme-colour synaesthesia, and a recommendation for future research to expand the scope of analysis across synaesthesia subtypes.

Another important consideration when contextualising the findings is that most experimental research on synaesthesia is conducted with adult participants. Of the 23 studies included in this review, 15 involved adults. Given that synaesthesia develops over time during childhood, it remains unclear at what age potential cognitive and learning advantages emerge, making it difficult to determine their applicability to specific educational stages. Furthermore, studies involving child participants that support Theme 1 were limited by small sample sizes. For example, Green and Goswami (2008) found that incongruent colours impaired number recall, yet the study included only six synaesthetes. This further constrains the strength of findings across the literature and limits their immediate applicability to teaching and learning contexts.

We recognise that consistency testing constitutes the field's gold-standard procedure for confirming synaesthesia and has been widely used for more than a decade. Where included studies did not report a recognised consistency measure, we explicitly reflected this in our quality appraisal and tempered inferences accordingly. This approach preserves historical and child-focused evidence (where formal testing has been less consistently reported) while maintaining scientific rigour through transparent weighting.

The ability to associate sensory information in an atypical way, whether consistently or intermittently, may still enhance memory, attention or cognitive processing in meaningful ways, although this has not yet been extensively researched. Most experimental studies tend to select for the intensity of synaesthetic experiences. Future research could build on this, suggesting that pedagogical strategies designed to support synaesthetic learners should not be limited to those with the most pronounced or stable experiences. Instead, these strategies should account for the broader spectrum of perception. This perspective aligns with inclusive educational approaches, recognising that even subtle or variable manifestations of neuro-cognitive development may offer advantages that can be leveraged for learning within a strengths-based paradigm.

A smaller limitation to note is that phenomenological subtypes of synaesthesia were rarely reported in the included studies, which limited any analysis of potential differential effects. For clarity, projectors experience their concurrents as if they are located externally on the inducing stimulus or in external space (e.g., a printed letter appears coloured on the page), whereas associators experience their concurrents internally in the mind's eye without an externalised percept. This distinction may have educational relevance. For instance, imposed colour schemes might plausibly interfere more

with projector experiences than with associator experiences, but the available data did not permit subgroup examination.

Conclusion

This review has highlighted synaesthesia as an overlooked aspect of neurodiversity within inclusive educational practice. While existing experimental research is limited in scope, it nonetheless suggests promising cognitive and learning advantages for synaesthetic individuals, advantages that remain largely untapped in adapted pedagogy and targeted interventions. Recognising synaesthesia within the neurodiversity framework not only validates its presence in educational contexts but also opens the door to innovative teaching strategies that nurture and enhance these unique cognitive abilities from a strength-based perspective. Future research should further explore how synaesthesia can be leveraged to inform differentiated instruction, ensuring that inclusive education extends beyond accommodating challenges to actively fostering diverse cognitive strengths.

AUTHOR CONTRIBUTIONS

Alexandra Sewell: Conceptualization; investigation; writing – original draft; methodology; writing – review and editing; formal analysis; data curation; supervision; project administration; software.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data and meta-data available upon request from corresponding author.

ETHICS STATEMENT

Ethics approval was granted from the University of Worcester Research Ethics Committee.

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