14th ICBEN 2023
18 - 22 JUNE
BELGRADE

14th ICBEN Congress on Noise as a Public Health Problem

A Review of the Effect of Noise on Cognitive Performance 2021-2023

[1]John E. Marsh[1,2], Jacqueline Gädtke[3], Sabine J. Schlittmeier[3]

[1]School of Psychology and Computer Science, University of Central Lancashire, Preston, United Kingdom
[2] Department of Health, Learning and Technology, Luleå University of Technology, Luleå, Sweden
[3] Work and Engineering Psychology, RWTH Aachen University, Aachen, Germany

Corresponding author's email address: sabine.schlittmeier@psych.rwth-aachen.de

ABSTRACT

In line with the topics covered by Team 4 of the International Commission on Biological Effects of Noise (ICBEN), a systematic literature review will be presented, which covers the years 2021 through 2023. A particular focus will be on the effects of noise on cognitive performance and the methodologies used to study these effects. "Noise", "cognitive performance" and several related terms were used within a search string to identify potentially relevant records. A stepwise procedure was adopted to reduce the large volume of records (5755) into a smaller number (105) to be included within the review. Several further cognitive-psychological reports (8) exploring how and why task-irrelevant background speech affects cognitive performance were also located through a manual search. This was justified on the basis that task-irrelevant background speech is considered one of the main acoustical challenges for workplaces at which principally cognitive performance must be achieved. The results of the selected empirical reports are analysed and the main trends in terms of topics studied and methodologies used are discussed.

Keywords: Noise, Cognitive Performance, Auditory Distraction

INTRODUCTION

Focusing on the influence of noise on cognition, this review examines and highlights the past developments in this influential research area [1-113]. Covering the years 2021-2023, a literature search was conducted within MEDLINE Complete, PsychInfo, Scopus and Web of Science databases. To maintain consistency with previous reviews (e.g., [114]), the same search string, designed with phrases, but without truncations was adopted. The searches were set up to identify relevant articles through search term matches within titles, abstracts and keywords of candidate records: ALL=("Noise" OR "Sound") AND ALL=("Cognitive Performance" OR "Cognitive work" OR "Cognitive activity" OR "Cognitive ability" OR "Cognitive task" OR "Mental work" OR "Mental task" OR "Mental processing" OR " Memory task" OR "Working memory" OR "Executive function" OR " Attentional focus" OR "Attentional capture" OR "Problem solving" OR "Adaptive behaviour" OR "Human behaviour" OR "Speech intelligibility" OR "Coping") AND ALL=("Work" OR "Job" OR "Public place" or "In public" OR "dwelling" OR "Building acoustics"). Indexes=MEDLINE Complete, PsychInfo, Scopus, Web of Science. Timespan=2021-2023. This search method, in combination with the selection procedures described below, resulted in 105 empirical reports for inclusion within this literature overview [1-105].

The search string was first executed on the 23rd of May 2022, and was repeated on the 2nd of March 2023, yielding 5755 records in total. Following the second search, the PRISMA [115] scheme was used to reduce the number of records for inclusion. Prior to screening, 1666 records were removed because they comprised records (e.g., duplicates, editorial statements, contents tables) that did not meet the goal of presenting an overview of empirical reports. The abstracts of the 4089 remaining records were screened, resulting in the exclusion of 3894 additional records because they did not meet criteria of interest or one of five exclusion criteria adopted: (i) already reported in the last ICBEN review [1]; [ii] The topic of the report fell outside ICBEN area 4; [iii] there was no report of original empirical data (the record was an overview article or meta-analytical review); [iv] no adult participants were included (the reports focussed exclusively on children or adolescents; [v] The record only reports neurophysiological measures. Therefore, 195 records were sought for retrieval, of which 20 were unable to be retrieved. A further 90 records were removed at the full-text screening process because it became obvious in the body of the text that they did not satisfy the criteria, or they comprised a longitudinal study, or a conference proceedings paper that was not peer-reviewed. This procedure resulted in 105 records for inclusion in the current literature overview [1-105]. A further 8 [106-113] empirical reports located independently of the literature review were also included, the rationale and justification for this, is reported below. Thus, a total of 113 empirical reports, each comprising at least one empirical study (and thus dataset), concerning the effects of noise on cognitive performance were included in the report.

The concurrent presence of task-irrelevant background sound while engaging in a task that principally requires cognitive processing is a fundamental acoustic challenge for individuals within work-place settings. Thus, a search was performed for records from basic (e.g., non-applied) research that addressed the characteristics of task-irrelevant speech that have the power to impair concurrent cognitive performance and why (via which hypothetical cognitive mechanism does the disruption occur? E.g., Attentional capture *vs*. Interference within short-term memory?). This revealed eight further reports for consideration that were not found using the literature search based on the search-string. Records were retained in the overview if they matched the search-string, regardless of whether they included a test of background speech as a noise condition. However, records of basic research studies that exclusively tested the impact of non-speech signals such as sequences of music, or sine-tones on cognitive performance, were neither searched for, nor included.

The overview included studies that reported objective measures of cognitive performance, as well as those that only reported subjective ratings of perceived performance in the presence of background sound. The rationale is that this permits inclusion of field studies for which noise conditions cannot be controlled and systematically varied, thereby restricting opportunities to investigate the impact of such noise on objective performance measures. This relaxation of a strict criterion for the inclusion of only studies reporting objective performance data via a search-string, enables the inclusion of field studies that can convey valuable insights for the recommendations of future research directions as well as remedial actions.

LITERATURE REVIEW

General information

Based on the consensus of the authors, the reports included in this overview were pre-structured by initially dividing the research reports into applied and basic research groups. Of the 105 records included, 33 reports were classified as applied research [5-7, 10, 21, 22, 26, 32-35, 40-42, 47, 50, 52, 58-60, 62, 64, 66, 73, 76, 77, 85, 86, 88, 90, 95, 98, 111] in one group and the remaining 80 reports were categorised as basic research [1-4, 8, 9, 11-20, 23-25, 27-31, 36-39, 43-46, 48, 49, 51, 53-57, 61, 63, 65, 67-72, 74, 75, 78-84, 87, 89, 91-94, 96, 97, 99, 100-110, 112, 113] in a second group. The information compiled on the applied research reports can be located in Table 1, and the information assembled on basic research can be found in Table 2. Both tables appear in the appendix.

Since a strict criterion could not distinguish the assignment of a given report to applied or to basic research, the authors adopted the following rule: A report was assigned to the applied research group if it: comprised a field study (e.g., within an open-plan office, hospital, construction site, or bank) [e.g., 32, 40, 88, 98]; considered a certain work-space or work-place (e.g., an open-plan office or open-plan study environment; [e.g., 5, 26, 55]); or considered noise as one among a number of multi-modal environmental stressors (e.g., lighting, vibrations, air quality [e.g., 33, 34, 66, 77]).

In the forthcoming, the initial focus is on key aspects of the applied research reports. Subsequently, fundamental elements of the basic research reports will be considered.

Applied Research Reports

Sound Quality

Most applied research reports in the considered period dealt with background speech and office noise as experienced in an open-office office (OPO) [5, 10, 26, 33-35, 50, 52, 58, 64, 73, 76, 85, 86]. Furthermore, the effect of broadband noise or music on performance was investigated [7, 10, 40, 50, 59, 76, 98], as well as of traffic noise (e.g., traffic noise through open windows in OPO [58, 86], or bus drivers [66, 77], respectively). Some studies also focused on other working environments and its related sound environment e.g., construction or mining sites [7, 40, 41, 76, 90], operation rooms [22, 42, 98], and industrial manufacturing [6, 21, 26, 59, 62]. Finally, a number of these studies examined the potential of masking sounds, such as music [22, 98], or the use of Active Noise Cancelling headphones [63, 73] to counteract the adverse effects of background noise on cognitive performance.

Field studies investigating employees in their professional working environment mostly observed them in their standard acoustical settings without manipulating different sound conditions [32, 77, 88]. However, some field studies compared workers' cognitive performance and/or subjective experiences either between loud and quiet locations within the same working environment [6, 62] or between loud and quiet time frames during the observation [42, 90]. Notably, one field study even manipulated noise and investigated the effects of noise, different music types and levels for nurses [98].

On the other hand, laboratory studies focusing on specific workplaces were more diverse in their employment of noise manipulations. Applying the aforementioned sound conditions, the noise exposure to differing conditions was manipulated comparing different sound qualities [26, 41, 50, 59, 60, 64, 85, 95] or sound levels [5, 21, 33-35, 52, 58, 66, 86, 111], and combinations thereof [7, 10, 40, 73, 76].

Laboratory studies including background speech often used multi-talker semantically meaningful speech as in e.g., broadcast, word, or dialogue snippets [e.g., 33-35, 50 60, 64]. Two classroom-focused studies combining typical non-speech classroom sounds with speech were also included here due to its relevance as a work-place [47, 60]. Noise exposure experienced as in an OPO was simulated using the sounds of e.g., operating equipment (printers, fans, computers), footsteps, clinking glasses, ringing telephones and paper rustling with soft background speech or speech snippets also frequently being included in the office sound environment [10, 33, 34, 50, 73, 85].

Other noise sources like broadband noise stimuli consisted of white or pink noise [e.g., 10], whereas music stimuli included pop songs or classical music [22, 40, 50, 76, 98]. Sequences of pure tones were adopted in one study as well [95]. Urban environmental noise stimuli consisted of sound recordings of a public place accompanied by traffic noise [73]. Notably, traffic sound was not only manipulated in its loudness levels [e.g., 111], but also in its macro-temporal patterns [see e.g., 58, 86]. Recordings of construction and industrial sound environments were presented to participants, functioning as a combination of environmental and workplace related sounds [7, 21, 26, 41, 40, 59, 76]. In most controlled laboratory studies a quiet condition was included, serving as control [5, 7, 26, 40, 41, 47, 50, 52, 58-60, 64, 66, 73, 76, 86, 111]. Furthermore, some studies investigated the influence of visual stimuli on the perception of the acoustical environment [33, 34, 111]. For example, one study investigated the effect of the presence of plants on the cognitive performance of participants in a Home Office environment, where traffic noise exposure through open windows was simulated [111].

Sound Pressure Level and other Acoustical Aspects

Most applied studies, unsurprisingly, gave specific attention to sound pressure level and/or loudness [5, 7, 10, 33-35, 40, 52, 58, 66, 73, 76, 86, 111], but some studies also considered other (psycho-)acoustical parameters, like reverberation time or roughness [35, 52, 86]. Furthermore, exploration of multi-stimuli environments manipulating audiovisual properties (e.g., light [33, 34, 111], or the presence of plants [111]) was undertaken.

Many studies discriminated between at least two sound levels, categorising sound levels often into “low” and “high”. “Low” levels of environmental noise exposure in field studies or manipulation in the laboratory ranged between 45 and 60 dB [10, 98, 111]. Some studies use an increase to reach levels categorised as “high” in other studies [e.g., 111]. For “high” levels, noise stimuli in the studies were presented, or recorded on site, with sound pressure levels between 65 and 85 dB [7, 21, 26, 32, 40-42, 47, 50, 59, 60, 62, 73, 76, 77, 90, 95, 98]. Furthermore, some studies examined the effects of an average exposure of even more than 85 dB(A) [6, 21, 62, 66, 90], which is a sound pressure level often associated with potential health impairments.

Studies focusing on an office environment tended to use lower noise levels compared to field studies or studies related to the industry or construction sector. Here, noise levels were typically around 45 to 60 dB [10, 33-35, 50, 58, 64, 66, 85, 86], or even lower (30 dB(A) in [52]). However, some studies used comparatively high sound pressure levels of around 70 dB, e.g. for stress-induction [5, 26, 76]. If records used and reported on a “low” noise condition, sound levels of 20 to 40 dB(A) were typically used [7, 21, 58, 64, 66, 76, 85, 86, 111], but control/baseline conditions ranged up to 50 to 55 dB(A) [26, 59]. As previously mentioned, some studies also manipulated further (psycho-)acoustic parameters besides sound pressure level or loudness [35, 52, 86], e.g., Quiet Time Distribution (QTD) of traffic noise [86]; roughness, tonality, or the sharpness of noises omitted by operating heating and ventilation equipment [52].

Cognitive performance during noise – objective measures

Many studies, especially laboratory studies, employed cognitive performance measures which target a specific cognitive domain, function, or process. A special focus was placed on working memory and associated tasks: The forward (i.e. serial recall) or backward digit span task was administered in several applied studies [7, 33, 34, 47, 60, 64, 76], as well as backward counting [58, 59], and the n-back task [7, 10, 52, 76]. To manipulate task load, some latter studies included an 1-, 2-, or 3-back task, or combinations thereof [52, 76]. Attention and inhibition were measured using the Stroop task [10] or the Go-No-Go task [66]. Sustained attention was measured with the continuous performance test (CPT) [10]. Furthermore, more complex arithmetic tasks [5, 50, 73] were used to assess working memory performance. Notably, different tasks to quantify verbal functions and processing skills were applied, such as the English Reading Comprehension Task (ERCT) [111], a paired-associate recall task using noun pairs [60], a verbal (phonemic) fluency measure [58, 59], the Rey auditory verbal recognition memory test [58] and the Rey Test (REY) [59]. Moreover, tasks which test more general executive functions like creativity, problem-solving, or abstract reasoning were measured, i.e., the remote associate test [10], the Tower of London test [21], a verbal reasoning task [50], and the Advanced Raven’s Progressive Matrices Set II [50], respectively.

On the other hand, cognitive tasks that are considered to be related to a specific job or workplace were also investigated. Most studies focused on an OPO environment, therefore many of the included cognitive tasks should test performance, which is commonly conducted in this occupational setting. For instance, a proofreading task [85] and a typing performance test [10] were deployed. Other work environments and work performances have also been explored. For instance, [40] and [41] employed a task wherein participants had to identify potentially hazardous openings in walls or floors on a construction site while being exposed to noise. Moreover, laboratory studies focused on the impact of traffic noise and vibrations, as well as further sounds on the recruitment of attentional resources, as experienced by occupational drivers [66, 95].

As previously mentioned, cognitive performance was rarely quantified in field studies. Still, bank employees [32], industry and building industry workers [e.g., 6, 90] and nurses [e.g., 98] were observed performing their normal work. Nonetheless, two field studies managed to include an objective measure of cognitive performance in their design: Simulating an operating room environment, one study rated the performance of naive medical students in a surgical procedure using a teaching simulator [22]. Similarly, the Subjective Workload Assessment Technique (SWAT) was used in another study to quantify the knowledge and recognition of critical processes and steps of medical staff at different phases of an operation [98]. Furthermore, one field study used a pre-post design whereby bus drivers performed in the Stroop task before and after they were driving their routes for an 8-h work shift and the corresponding noise exposure [77].

Subjective measures targeting cognitive performance

Cognitive performance effects induced by noise can be evaluated via objective performance metrics, as focused above, and a subjective approach involving the collection of participant self-assessments. For the latter, methodologies often involve administering questionnaires or individual rating scales that solicit participants' evaluations of particular aspects. In the applied studies, one of the most researched subjective assessments in regard to cognitive performance was subjective mental workload. Field studies frequently assessed participants' perceived workload, probably because noise effects on cognitive performance could not easily be quantified with a cognitive test battery. Several studies used a standardised rating scale, namely the NASA-TLX [26, 32, 52, 73, 111] or one of its adapted versions (see [22] for use of SURG-TLX). Other scales included the SWAT [98] or, the Individual-Charge-Activity (ICA) scale [34]. Furthermore, participants were asked to evaluate their own concentration or cognitive performance during a task under noise exposure, utilising measures such as a five-point Likert scale [64] or on visual analogue scales (VAS) [7, 76]. In a field study, a shortened version of the Work Ability Index was assessed in automotive industry workers and correlated with the average noise exposure level measured during the observation [62].

Closely related to the perception of mental workload is subjectively perceived mental fatigue, which has been measured in several applied studies [e.g., 111]. Here, standardised scales like the Swedish Occupational Fatigue Inventory (SOFI) [32, 76] were used, as well as correspondingly labelled VAS ranging from 1-100 [26]. Furthermore, subjectively experienced effort and disturbance in fulfilling the task demands during noise exposure were also assessed using various scales [64, 73].

Subjective measures of annoyance, mood and satisfaction

The effect of noise on further subjective experiences has been determined in various studies. Firstly and unsurprisingly, annoyance was addressed as the variable of interest in most studies exploring subjective effects of noise [26, 35, 52, 64, 73, 76, 86, 88]. Assessment of annoyance was conducted using the ICBEN scale [86], by applying the effort and frustration dimensions of the NASA-TLX [52] or by other rating scales [26, 64, 76].

Secondly, both field and laboratory studies assessed mood and affective responses in reaction to noise exposure. Instruments such as the State-Trait Anxiety Inventory-State (STAI-S) were utilised to quantify anxiety [73, 98, 111]. Similarly, the Copenhagen Psychosocial Questionnaire (COPSOQ) was employed in a field study to gauge the psychosocial status and occupational stress levels of employees [6]. Another study further quantified the latter using the Philip L. Rice job stress questionnaire [77], while the Self-Assessment Manikin (SAM) was used in a different study to gauge general stress levels [73].

The satisfaction of employees with their auditory and non-auditory work environment could potentially influence their work performance, as well as their psychological and physical health. Consequently, studies have explored employees' overall satisfaction with and the perceived pleasantness of their workplace [6, 33-35, 88, 111]. Among these studies, four specifically honed in on the qualities of the sound environment [33-35, 111].

Further noise effects and mediators

Several studies also assessed individual factors either as covariates in their analysis, or to determine moderating or mediating factors influencing the effects of noise on cognitive performance. Factors such as age [26, 60, 62], personality traits (e.g., extraversion) [21, 26, 50], gender [58], and IQ [50] received considerable attention. Moreover, the impact of noise sensitivity on participants' objective and subjective cognitive performance was examined in field [88, 32] and laboratory studies [26, 35, 52] using tools like the Weinstein Noise Sensitivity Scale [26, 32] and the Noise-Sensitivity-Questionnaire (NoiSeQ) [52], among others. Furthermore, one study also used noise sensitivity for balancing groups based on this individual characteristic [76].

Several studies also took psychophysiological measures in addition to performance related measures or subjective ratings. A substantial number of studies investigated the physiological effect of noise using electrodermal activity (EDA) [85, 52, 10], electromyogram (EMG) [52], electrocardiogram (ECG) [22, 42, 52, 76, 85], or by measuring hormonal changes [5, 76]. Conversely, neuroimaging techniques such as electroencephalography (EEG) were utilised to observe indicators for modulations in attentional states and workload [5, 40, 41, 73, 95].

A Summary of Empirical Findings from the Applied Research Reports

Over the reporting period, 33 applied studies were identified in the literature search, which examined the effects of noise on cognitive performance. Much of the focus–in field studies as well as in laboratory studies–has been on the effects of office noise in OPOs and/or background speech (e.g. [5, 10, 26, 33-35, 50, 52, 58, 60, 64, 73, 76, 85, 86]). However, a series of applied studies, in particular field studies, delved into noise specific to certain workplaces like construction and mining sites, operation rooms and industrial manufacturing (e.g. [6, 7, 21, 22, 26, 40-42, 58, 59, 62, 66, 76, 77, 86, 90, 98]).

Consistent with the latter, some applied studies realised high noise levels, for example in the studies dealing with noise effects in industry, mining and construction (typically around 65-85 dB; e.g. [7, 40, 41, 76, 90]). With this, the range of possible effects of noise on cognitive performance was extended, compared to the focus on moderate levels in recent years (cp. [2014]). Such broadening could prove beneficial, as certain mechanisms of action may be level-related and their mediating or moderating role between noise exposure and cognitive effects may only then be detectable if a sufficiently large level range is studied. (Of course, it's worth noting that high noise levels of approximately 85 dB(A) and above pose a risk of hearing impairment. Therefore, no one's unprotected ears, be they study participants or workers, should be exposed to such noise levels.) To investigate plausible noise conditions, applied studies on OPOs, office noise, and background speech generally utilised lower noise levels (typically around 45-60 dB; e.g. [33-35, 64, 85]). However, regardless of the specific level range, noise level plays a role for the noise effects identified in a series of the applied studies. Generally speaking, the findings from the reviewed applied studies suggest that as noise levels increase, both cognitive and subjective performance, as well as subjective well-being seem to deteriorate (e.g. [21, 26, 34, 35, 66, 85, 111]). This general noise effect might reflect noise acting as sensory stimulation, increasing physiological arousal. This hypothesis is corroborated by applied studies in which physiological measurements were collected and indicators of increased stress and arousal levels were found with noise exposure per se (compared to a "quieter" control condition) or with increased noise level (e.g. [5, 10, 42, 76, 85]). Remarkably, a substantial number of applied studies during this reporting period also collected (psycho-)physiological measures such as EDA, EEG, and hormonal concentrations [5, 10, 22, 40-42, 52, 73, 76, 85, 95]. This suggests an expansion of the use of methods in applied research into cognitive noise effects during the review period.

A comparable general noise effect is not observed in the reviewed applied studies when considering the impact of noise exposure on the various cognitive tasks used, as indicated by the performance objectively measured within these tasks. In fact, the effects of noise on objective measures of cognitive performance have been diverse, with some studies demonstrating decreased performance in the presence of noise (e.g. [5, 7, 21, 34, 40, 59, 60, 64, 66, 77]), others indicating no significant effects (e.g. [7, 22, 41, 50, 76, 85, 86]), and some even finding improved performance under certain noise conditions (e.g. [10]). However, due to the broad range of procedures and tasks used (aside from the different noise conditions), identifying a pattern behind the reported noise effects proves challenging. For example, the applied studies which reported impaired cognitive performance during noise, utilised attention and short-term memory tasks measures, Stroop task and problem-solving performance, and other tasks presumably tapping into executive functions. Yet, some of the studies which could not verify significant performance effects of noise also used short-term memory tasks and the Stroop task, besides exploring performance in tasks such as simulated laparoscopy, visual search and mental arithmetic.

The evidence appears to be clearer again when considering the results of the reviewed applied studies regarding noise effects on subjective measures and evaluations collected via questionnaires or rating scales. In field studies, where it is not easy to also administer cognitive-psychological tests to quantify the effects of noise on cognitive performance, subjective measures often provide the only source of information on cognitive noise effects. These measures are sometimes also collected in applied laboratory studies to supplement objective performance measures. The applied studies, which examined the subjective effects of noise often focused on subjective measures to target subjectively perceived cognitive performance (e.g. [26, 32, 98]), noise annoyance (e.g. [26, 35, 52, 64, 73, 76, 86, 88]), perceived stress (e.g. [6, 73, 77]), mental workload and mental fatigue [26, 32, 52, 73, 76, 98]. Additionally, subjective ratings were used to explore both auditory and non-auditory workplace satisfaction (e.g. [6, 33-35, 88, 111]). Overall, satisfaction was found to be lower in noisy conditions compared to a (quieter) control condition, or as noise levels increased, respectively. In fact, negative effects of noise were confirmed across all of these subjective dimensions, with subjective experiences and evaluations often appearing to reflect noise effects more sensitively than objective performance measures. For example, some studies testing office noise combined with speech could not verify an adverse noise effect on cognitive performance, but did so on subjective well-being [85, 50]. However, it should be noted that the applied studies employing background speech mostly agreed upon background speech being detrimental for cognitive performance and negatively impacting aspects of perceived well-being, such as stress level, affect and mental load (e.g. [5, 10, 33-35, 64, 73]).

Basic Research Reports

Sound Quality

Many of the basic research studies employed speech [19, 28, 37, 38, 51, 61, 72, 75, 80, 81, 100, 109], but the nature of the speech used varied. It included sequences of repeated, or changing letters [19, 37, 38, 43, 51, 57] or digits [27, 43, 65, 84], consonant-vowel syllables [24, 48], monosyllabic words [3, 11, 65], category-exemplars [72], or semantic associates played forwards or backwards [79]. Furthermore, some studies presented auditory sequences that included an unexpected change such as a deviant letter within an otherwise repeated letter (steady-state) sequence [3, 37, 38], or a change of voice/category/both [51] within a sequence of letters, or a category change within an otherwise categorically-homogeneous list sequence of words [72]. Baby cries were used in a single study [71].

Some studies adopted more continuous speech including: Proverbs with, or without, the appropriate sentence-end word [81], sentences of varying types (e.g., aphorisms, recipes, poems) [39], conversational speech [31], an audiobook chapter presented in participant's native language [100] or a language foreign to them [109], a weather forecast presented in a participants non-native language [36], radio interview [75] or other dialogue [93] in a participant's native language, or a story read in the participants native [29, 80] or non-native language [80], or presented in reverse [29]. In one study, the speech was presented in the participants' native language, but this was of non-determinable nature due to missing information [28]. One study presented sine-wave speech [24].

Many studies used broadband noise [56, 113] and this included: white noise sequences [8, 25, 28, 68, 71] or bursts [49, 69, 74], and pink noise sequences [4, 20, 44, 75, 103] or bursts [91]. Other studies used ambient noise [63] including air conditioning noise [61], fan noise [1], library noise [15], or traffic noise [61, 93]. Specific environmental sounds deployed in studies included phone ringing or a doorbell [18, 49] an audio recording of a phone vibration alert [106] a pressure washer [55], a car horn [112], or a police siren [25]. In some studies using environmental noise the diversity of the noise was manipulated (e.g., 8 car recordings [low diversity] vs. car recordings, sirens, trucks, aeroplanes etc [high diversity] [94]. In some studies the loudness and sharpness [82, 107] of background noise was varied, sometimes in addition to its acoustic roughness and fluctuation strength [82].

Sounds of nature were used in a cluster of studies ([53, 54, 61, 92] and this included a flowing river [61], dog bark [112], guinea pig squeaks [14], and bird song segments [14, 92]. Nature sound diversity was manipulated in one study wherein the influence of bird-song from 2 (low diversity) vs. 8 (high diversity) bird species was compared [94].

Infrasound [9] and ultrasound [17, 105] were used in a few studies and several studies used monaural [20] or binaural beats [4, 20, 78, 101, 103]. Many studies used tones, the frequency of which varied within or across studies [2, 8, 12, 13, 16, 23, 30, 37, 46, 56, 67, 70, 74, 83, 87, 96, 97, 99, 101, 102]. In two studies, tones were played rhythmically or arhythmically with to-be-attended visual stimuli [16, 46], or at fast tempo [46]. In another study tones were played with high or low metricality and with high or low regularity [87] thereby forming a musical sequence.

Music provided the background sound in other studies [61, 104, 110]. This included native language pop songs [89], modern music [45], relaxing music [101], piano versions of Disney or Anime songs [89], and classical music [45, 68] from which a rhythm only and melody only version was created in one study [110]. Emotion (e.g., sad or happy) was manipulated in one study through mode, tempo and articulation of the background music [104].

Speech Intelligibility and Level

Few basic studies manipulated the intelligibility of background speech. In one study, the intelligibility of speech was manipulated by locally reversing parts of the speech at 70 ms (~50% intelligible) and 140 ms (unintelligible) segments [39]. Unintelligible speech was presented in some studies by reversing the entire speech signal [29, 79]. Very few studies reported speech intelligibility via the Speech Transmission Index (STI) although it was measured at 0.9 in one study [75].

For background speech, steady-state consonant-vowel syllables were presented at 60 dB(A) and changing-state consonant-vowel syllables were presented at 57 dB(A) in one study whereby sine wave speech versions of the two sequences were presented at 62 dB(A) and 58 dB(A) respectively [24]. Sequences of repeated, or changing, letters or tones with or without a deviant were presented at 65 dB(A) in another study [37] and at 45 and 75 dB(A) in a further study [3]. In an additional study, sequences of digits or letters from a restricted set were presented at approximately 56 dB [43]. Sequences of consonant-vowel syllables were presented at 62 dB LAeq in a one study [62], monosyllabic words and digits were presented at 65 dB in another study wherein the signal-to-noise ratio was computed at 90% [65], and at 65 dB (A) in a further study [11]. Category-exemplars were presented in another study at between 65-75 dB(A) [72].

One study adopting continuous speech describes the intensity as “conversational speech level” [81] which researchers will generally consider to be around 60 dB. In a study deploying conversational speech, the signal was presented at 45 dB and 85 dB [31]. A background audiobook was presented at 80 SPL in one study [109] and a meaningful speech dialogue was presented at 70 dB in another study [93]. Background stories in a participants’ native or non-native language were presented at 67.5 dB SPL [80]]. Background speech of indeterminable nature but presented in a participant’s native language was presented at 55 dB [28] in one study, and meaningful speech taken from a classic novel was presented between 46.79-78.48 dB [100] in another study. A study using task-irrelevant baby cries presented them at 53.6 dB [71].

For broadband noise, one study presented pink noise at 68 dB(A) [44]. Other studies deploying continuous broadband noise, presented the sounds at 54 dB [71], 60 dB(A) [56], 75dB(A) [113], and 85 dB [25]. Bursts of broadband noise were presented at 80 dB [37], 100 dB(A) [108], or with a range between 58-72 dB [69].

The sound pressure level of environmental sounds differed between studies. Library noise was presented at 78 dB(A) [15], “ambient noise” at 65 dB [63] and road traffic noise at 70 dB [93]. In one study, pressure washer sound was presented at 85 dB(A) and 70 dB(A) when attenuated [55], and in other studies environmental sounds were presented at 75 dB [49]. In further studies an audio recording of a phone vibration alert was presented at 62 dB(A) [106] and police sirens were presented at 85 dB [25]. Dog barks and car horns were presented at 75 dB [112] and guinea pig squeaks and bird tweets were presented at 68 dB in another study [14].

Infrasound was presented at 80–90 dB [9] and binaural beats at 75 dB [4]. Tones were presented between 55 and 65 dB (e.g., f1 = 65 dB and f2 = 55 dB [56]), 55 dB SPL [30], 60 dB SL [96], 65 dB (A) [37], or 65 dB [83, 87], 70 dB [70], 75 dB [13, 49, 102], 80 dB [99] and up to 120 dB in one study [17]. In studies using music, classical music and its melody only, and rhythm only versions, were presented between 70 and 80 dB [110].

Some studies used intensity increments of 5 dB(A) (e.g., 45-65 dB(A); e.g., for traffic and air-conditioning noise [61]; or 65-75 db(A) for fan noise [1]) and increments of 0.3 for reverberation time values (e.g., 0.3 – 1.5 s, for speech and music [61], see also [107]). In other studies, noise signals were presented at four loudness levels (2.90 – 8.25 Sone).

Other studies did not report loudness [e.g., 23, 36, 38, 45, 57, 74, 84, 97, 103] or merely mentioned that sound was presented at a constant level for all participants (e.g., a setting of “20” [29], or “80” on the laboratory PC’s volume mixer [94]). Some studies reported that loudness was individually determined [101, 104] for example, as the maximum loudness a participant reported comfortably tolerating [104], or to moderate intensity [68]. In other studies level was determined by the participants based on their hearing thresholds [18, 105] with sounds then being presented 5 dB above and 10 dB below these thresholds [105]. It is important to note that level may be impossible to gauge for online studies [19, 38, 39, 51, 79] including intervention studies running through mobile applications [54].

One study included the variability of sound (LA5-LA95, computed by the difference between 5% and 95% percentiles of the A-weighted sound pressure level using fast time weighting) and the equivalent sound pressure level (LAeq c, which corresponds to the entire duration of a sound sequence) [75]. Within this study, the LA5-LA95 was 1 for pink noise and 24.2 for speech, and the LAeqc was 65 for pink noise and speech.

Cognitive performance during noise - objective measures

The most frequently used task in the context of basic research was the visual-verbal serial recall task (accuracy of serially ordered report of visual items; [3, 11, 16, 19, 24, 27, 36-39, 44, 48, 51, 57, 75, 79, 81] and its variants which tap short-term/working memory. These included a version with distractor visual digits [16], auditory-verbal serial recall [75], forward and backwards visual [27, 94], and auditory digit span [65]. In several studies a visual-verbal spatial serial recall task [24, 48] including the Corsi-block task ([71, as assessed through accuracy, time taken to make first response, total execution time and length of sequence]) was administered. Other tasks tapping short-term or working memory included the visual running memory span task (e.g., report the last n digits from a just-presented sequence of varying length [84]), the missing-item task (report the item from a well-known set that was not presented within a list [57]) and the Sternberg memory task, that requires a decision as to whether a probe digit occurred in a just-presented short (2-digits) or longer (5-digits) sequences [108]. Further, auditory working memory was assessed in one study using a same/different comparison task for auditory sequences (e.g., comprising tones [12]).

Working memory was also addressed in a number of studies through use of an n-back task. This was administered at a single level of difficulty [93, 105] or at different levels of difficulty [1, 4, 13, 55, 75, 82, 89] and accuracy and reaction time to make each response was recorded [1, 75, 89, 105]. Some studies used variants of the n-back task [78, 94, 112], for example, one study used a dual version of the n-back task (see also, [94]) wherein one task was presented in the visuo-spatial modality (colour-object changes location) and one was presented in the auditory-verbal modality (verbal presentation of digits), signal detection, reaction time, and intra-subject response time variabilities were measured [78]. The timeload dual back task was used in another study [101].

Visual working memory was addressed in several studies. For example, in one study participants were cued, or not, to a location of previously presented (and encoded) items and requested to change the orientation of the cue to match the encoded item. Signal detection scores, guess rates 1/precision scores were computed [28]. Similarly, a further study used a task involving signal detection of masked or unmasked visual targets [8]. A delayed match-to-sample visual-spatial task was used in another study, which incorporated different levels of difficulty: participants compared target and probe displays comprising a different number (2 to 5) spatially distributed squares of different colour [103]. Working memory was also tapped through mathematical verification tasks [106] and mental arithmetic tasks [38] either performed on their own, or presented as a dual task whereby participants were to remember word pairs presented with to-be-solved mathematical equations [38]. Some tasks required an episodic long-term memory component such as free recall of supra-span lists of words [72, 103, 104] and old-new recognition tests for pictures or vignettes of urban scenes [45]. Implicit motor-skill learning was measured with the serial reaction time task [46], with several (12) target locations in one study [74].

Attentional and inhibitory mechanisms were addressed in other tasks by way of visual flanker tasks of varying difficulty [20] (including a task in which flanker letters either matched (congruent) or mismatched (incongruent) central target letter [83]), the Stroop task ([31, 68, 97] computing, for example, conflict processing (via incongruent trials [68]), the Go-NoGo task [17, 67] for which reaction times were measured, the attentional blink paradigm in which participants were to identify, in a rapid serial-visual presentation, letters occurring at two time-points [102], and a related temporal order judgement task to determine which visual stimulus occurred first (or last) following short or long delays [91].

A battery of tests or measures was adopted in other studies [9, 53, 110]. These included use of the Attention Network Test, which measures three hypothetical attentional networks – alerting, orienting and executive control [53]. Attentional orienting was addressed in one study through the competitive attention task (CAT), wherein participants were required to categorise target sounds presented to the left ear, right ear, or both ears, as high or low pitched typically following the presentation of a central visual cue (an arrow) that either pointed to the left, right, or both sizes [18]. For the CAT, reaction times and percentage accuracy were computed [18]. In other studies, sustained attention was measured with the CPT [2, 17] (for which reaction times were measured) and psychomotor vigilance task [101, 107].

Attentional orienting (e.g., to an unexpected auditory item [deviant]) was measured in other studies wherein the focal task required binary categorisation of a visual stimulus (e.g., a digit as odd vs. even [49]), or an auditory stimulus (e.g., as short or long, [80]). Attention was further investigated in several studies deploying visual detection, monitoring and tracking tasks. One study used a visual detection task within which participants were required to detect/report a stimulus change (e.g., colour change) in central fixation or in the periphery [70]

Related tasks required participants to recall a target's shape and location for which reaction time and accuracy performance measures were taken [61], and change detection [56] for which hit-rates were computed. A similar task required visual target detection following spatially cued rhythmic flicker [92]. In a further study, participants performed visual search for a target of predefined colour in a 4-element array with a decision about the target's orientation (vertical vs. horizontal) whereby the display was preceded by a distractor array comprising colour elements for which one changed to either match the target colour or a non-target colour [99].

A single study used a task that required monitoring an auditory sequence for particular digits and measured with reaction time [43], and further studies required participants to detect and determine the digit sequence spoken by a target speaker of a certain gender [14]. Similarly, studies also required participants to monitor: for occurrences of a phoneme within speech [109]; a letter series for changes in colour or both capitalisation and colour [96]; or a visually-presented fixation cross for a change in colour, measured via reaction time [87].

A tracking task [30, 107] with different levels of difficulty (e.g., a variable number of cued targets must be attentively tracked [30]) was used in one study. Two studies adopted visual search tasks: In one study, participants searched for a single or double colour change with varying numbers of visual items [23]. In another study, participants searched for an "agentive" element (e.g., animal or human) in internal (e.g., kitchen, bathroom) or external (e.g., garden, street) environments [69].

Several studies used tasks that tap executive function(s) including the Wisconsin card-sorting task [68], a dimensional change card sorting task [63] and an auditory attentional switching task [65]. Dynamic decision-making tasks were used in two studies. One involved the control of a dynamic system for which some actions delay or prevent other decisions [113] and another employed system monitoring and resource management tasks of varying difficulty [107].

A few studies used tasks aimed at assessing comprehension. This included a listening comprehension task assessed with information, integration and inference questions [65, see also 100], and multiple choice reading comprehension tasks [25, 29] including those measuring reading completion time [25].

Creativity was measured in one task with administration of the Alternate Uses Task to measure divergent thought [63] and team problem-solving performance was measured in another study with a puzzle assembly task [15].

A number of studies also used additional measures that went beyond the data from the behavioural tasks. For example, two studies used eye-tracking to determine gaze behaviour [45]. Three studies used pupillometry [23, 30, 80] to determine the allocation of cognitive resources to targets and distractors, and another used electrodermal recordings to measure arousal [28]. Other studies use MEG [70] or EEG [15, 20, 30, 31, 82, 87, 96, 97, 101, 103, 106, 107] to, for example, measure response to auditory deviants [30], or explore the possibility that auditory steady-state responses vary as a function of visual workload [96]. fMRI was recorded in one study to determine functional connectivity [13]. In other studies ECG was used [15, 107] to, for example, record stress and arousal [15] as computed by, for example, HRV [106, 108]. Moreover, in one study, ECG and EMG were used to record resting vagally mediated heart-rate variability (vmHRV) as a moderator of the auditory affective startle response [108]. A further study used physiological measures of stress (as measured hormonal concentrations of cortisol, and noradrenaline, heart rate variability and blood pressure) [75].

Subjective measures targeting the effects of noise on cognitive performance

One study used VAS at the end of each noise condition to assess noise-induced annoyance and subjective fatigue [1, 101] and an Intrinsic Motivation Inventory to tap motivation [101]. Noise annoyance was measured in other studies according to the ISO/TS15666 standard scale [93]. Another study used measures of psychological stress that included subjective noise annoyance, as measured by Swedish Occupational Fatigue Inventory SOFI, workload and fatigue [75]. In a further study, participants used a VAS to rate sound on the dimensions of valence (negative vs. positive), arousal (calming vs. agitating), annoyance (not at all vs. extremely annoying) and loudness (barely audible vs. extremely loud) [44]. Another study addressed the diversity/monotony, pleasantness and beauty of a soundscape based on a VAS [94].

Subjective disruption was measured via metacognitive beliefs whereby participants were given a verbal description of the sound and asked to indicate how disruptive it would be, or were presented with sound stimuli and asked to rate their disruptive before and after a block of visual-verbal serial recall trials [11]. Similarly, in another study [37] participants made subject confidence judgements concerning their performance after each trial.

Similarly, in another study participants' perceptions of the interfering or facilitating effect of background music were recorded on a -5 to +5 scale [110] and participants' perceived state of arousal [110] was also measured. Mood was measured in another study with the Brunel Mood Scale [101]. Participants also rated their pleasantness and affect in another study wherein they were also asked if they heard sound that was aimed to be presented slightly above, or below, hearing threshold [105]. In a further study, participants were asked about their perception of the sound and its rhythm [16]. A further study [89] requested participants to answer questions about background sound on a Likert scale: Items included whether the participant thought they were in rhythm with the music and whether they noticed the sound level of the music was changing. In this study [89] participants were also asked about their feelings concerning the task (e.g., like – dislike, boring – interesting) and their feelings related to the music (e.g., wanting the music to be turned off, wanting to listen to the music more). In an intervention study, participants subjectively assessed their engagement in deep learning, academic Procrastination and academic self-efficacy [54]. A study, focussing on potential distraction by cell phone vibration noise, involved administering a compulsive cell phone use questionnaire to participants [106].

Subjective workload was assessed in several studies with the NASA-Task Load Index (TLX) [82, 96, 97, 107] or a variant (Noise TLX [55]) and using the Borg centiMax (CR100) scale [96]. Another study used the Dundee Stress Test to measure subjective task load [2]. In an additional study study, participants completed questions about the perceived difficulty of a reading comprehension test after the target passage had been presented in the presence of background sound [29]. A further study requested participants to complete strategy questionnaires to try to determine, via the participant’s self-report, the cognitive process used to memorise visual stimuli [84]. To address internal, in addition to external distraction, one study also administered a mind-wandering questionnaire to participants [2].

A Summary of Empirical Findings from the Basic Research Reports

Multiple strands of research pervade the basic science reports. A perennial endeavour has been to examine the characteristics of background sounds with the capacity to disrupt performance, while related attempts have been made to isolate cognitive processes that render a focal task susceptible to disruption via the presence of task-irrelevant sounds. The two research strands are often not mutually exclusive. For example, a theoretical account that drives much research–the interference-by-process view–suggests that auditory distraction is a joint product of the properties (e.g., cognitive processes) of the prevailing mental task and the characteristics of the to-be-ignored sound.

In this way, a continued focus of basic research has been to attempt to clarify and characterise the perceptual and cognitive processes that render focal task processing vulnerable to disruption from task-irrelevant sound. Due to the Covid-19 pandemic, several studies were undertaken online [e.g., 38, 51, 79] with one study verifying that auditory distraction effects could be reliably studied via the internet [19]. In the selection of basic reports included here, one study supports the notion that seriation (keeping track of serial order) is a necessary prerequisite for task susceptibility to disruption produced by acoustic changes within sound [38], but other studies refute this suggestion [84]. For example, two studies [24, 48] found that memory for the order of different spatially presented dots on a screen was not disrupted by a to-be-ignored sound that contained acoustic variation, which suggests that not all order information in short-term memory is susceptible to disruption by changing-state sounds. Further work questions the notion that the disruption produced by sequences of changing against repeated items (the changing-state effect) is driven by preattentive perceptual processing that the participant is not conscious of [11]. Work has established that participants are in fact consciously aware of the differential disruption produced by speech with different acoustic properties (e.g., steady-state, changing-state, deviant) [11, 37]. These studies appear to raise questions about whether the irrelevant sound effect is really the result of an interference between the deliberate process of keeping track of the order of visual-verbal items and a preattentive process that registers the order of acoustic changes within the sound, as the interference-by-process account holds. Participants' awareness concerning the disruption produced by different varieties of background sound may raise questions in future research about why some individuals prefer to study with an acoustic accompaniment. At odds with previous studies, loud sounds (75 dB[A]) were more disruptive than soft sounds (45 dB[A]), but this occurred regardless of the acoustic variability of the sound, which supports the notion that the changing-state effect per se is not influenced by sound pressure level [3].

Another wave of research focuses on the top-down control of auditory distraction. On this topic, research has shown that increasing task-engagement, implemented through increased reading difficulty, does not reduce disruption of reading comprehension by meaningful background speech [29] thereby contradicting previous research. Furthermore, another study [37] failed to replicate previous findings that increasing task-difficulty (through adding a visual noise to to-be-remembered items) reduces the disruption produced by auditory sequences conveying a deviant item [37] thereby calling into doubt the role of top-down control in attenuating distraction. However, the disruption of visual-verbal serial recall from to-be-ignored meaningful sentential speech has been shown to be reduced by pre-exposure to the auditory sentences, but only if this foreknowledge comprised at least partially intelligible material [39]. This work suggests a role of top-down control in distraction resistance, at least from material likely to divert attention due to intrigue. The finding that training in a dual, as compared to single, n-back task reduces the disruption of visual-verbal serial recall by task-irrelevant meaningless speech suggests that attentional control may play a role [36] in attenuating auditory distraction even in situations wherein background sound, lacking intelligibility, is unlikely to divert attention. Auditory distractors that were previously associated with high monetary reward, vs low reward or no reward, are more potent at disrupting auditory task performance when presented to an unattended ear while the participant identifies targets presented to the attended ear [43]. This suggests that stimuli previously associated with reward bypass top-down control. The unexpectedness, or predictability, of sound was manipulated in several studies [e.g., 18, 30, 49, 56, 67, 74, 92, 99] and the common finding is that unexpected, deviant (oddball) sounds impair concurrent performance [67, 74].

Various studies explore the extent to which to-be-ignored sound is analysed within the cognitive system [51, 72, 79, 81]. Convergent evidence suggests that the meaning of background sound is processed [51, 72, 79, 81] and influences later task performance even if its earlier concurrent presentation with visual memoranda does not disrupt performance [79]. Whether the semantic content of task-irrelevant sounds are extracted pre-attentively is debated [51, 72]. However, one study concludes that the disruption produced by a categorical change within to-be-ignored sound is distinct from that produced by an acoustic change: the two disruptive effects appear to be additive and while the latter attenuates over time, the former demonstrates no sign of habituation [51]. Indirect indicators that meaningful against meaningless background sound is differentially processed in the absence of impairing behavioural task performance has been obtained through pupillometric measures [80].

Another theme identified within the basic research reports was a focus on *facilitation* produced by background sounds. Improved performance associated with presentation of binaural beats, was observed on a dual task [78], flanker task [20], visuo-spatial working memory task [78, 103], word list recall task [103] and mental fatigue measure [101] However, such improvements were sometimes qualified by the nature on the binaural beats including the Hz at which they were delivered and whether they were embedded within a given broadband noise [4]. Broadband noise such as pink noise enhanced flanker task performance [20]. In one study, performance was better in broadband noise than in ambient noise for complex decision-making [113], but no silent condition was deployed. Relative to a quiet control condition, broadband noise and background speech improved performance in a visual-working memory task [28]. Speech also improved performance in the context of listening comprehension, working memory and auditory attentional switching tasks [65]. A raft of studies demonstrated cuing effects [14, 16, 23, 56, 69, 83, 87, 91, 102] whereby the presentation of an auditory item at some close onset asynchrony to, or in rhythm with, a visual presentation modulated performance. In one study, the presence of music enhanced memory for visual urban scenes [45], and in others, exposure to nature sounds as part of an intervention study [53, 54] led to improvements in well-being and flow state in addition to maintenance of an alert state [53] resistance to academic procrastination and improvements in deep-learning and academic self-efficacy [54]. While such facilitatory effects of background sound exposure are undoubtedly interesting, they often occur in rather contrived empirical settings and so their relevance for everyday cognition is questionable. Furthermore, in many cases the cognitive mechanisms behind facilitation via background sound is yet to be elaborated. This lack of theoretical specification was also observed in explanations of the influence of sound on complex task performance via sound [e.g., 15, 63, 107, 113], or the impact of sound on various tasks tapping attention [e.g., 31].

Gender differences were revealed in some studies regarding objective performance measures, with differential cognitive effects of noise seen under varying noise intensities and task loads [1, 113], and subjective ratings [1]. The impact of noise on certain cognitive tasks also appears to be age-dependent, with older individuals experiencing more noise-induced disruptions or distraction than younger individuals [18, 49]. Individual personality characteristics, including noise sensitivity and affinity for music, influence cognitive noise effects [12, 61, 93]. In the basic studies too, subjective self-assessments also indicate that the presence of noise can exacerbate perceived workload and physiological stress [75, 97].

CONCLUSIONS

The overview of applied and basic research reports published during the period 2021–2023 and included here, demonstrate some cross-over. However, in many ways the body of literature within the two research fields is also distinct.

A striking difference between the applied and basic reports within the 2021–2023 period covered was the frequency with which subjective performance data was gathered. While a few basic research reports collected subjective measures such as that of workload, stress, annoyance and metacognitive beliefs, they tended to focus on the collection of objective data. In contrast, the collection of subjective data was far more common in applied research reports. This likely reflects both practical and methodological considerations. Researchers specialising in “basic” experimentation, may be more focused on interpreting objective data and may struggle to see the point of including subjective data for which participants may have little insight into their objective performance. That is, being disturbed (e.g., objective performance decrement) does not always flow from participants’ self-reports of feeling disturbed in the presence of background sound. In basic research, asking participants to comment on their perceived workload, annoyance with the sound or whether they judge it to be disruptive might be considered secondary to the central aims and goals of researchers e.g., to establish characteristics of the task and/or sound that dictates auditory distraction. However, a strand of recent research studies have found that participants’ objective and subjective performance (e.g., metacognitive judgements) are well-calibrated in some settings. In applied studies, including fieldwork, the collection of objective data was collected infrequently. This likely reflects a lack of feasibility – management of companies may not be willing for staff to spend their work time undertaking cognitive-experimental tasks. They may, instead, prefer employees to be observed going about their everyday working activities. Further, the concept of “annoyance” has much more currency within the applied setting, wherein legal regulation and policy development is influenced by annoyance expressed by the general population. Researchers in the applied domain may thus place importance on both the object and subjective data so as to provide a more complete picture for assessing the acoustic environment in a human-centred fashion.

A key disparity between applied and basic research relates to the background sounds under consideration. While the importance of assessing the power of background speech to disrupt performance in both settings is crucial, the nature of the speech deployed is more nuanced in the basic research reports. For example, in basic research reports speech is often contrived – such as sequences of repeated, or changing syllables, single sentences or proverbs with an unexpected sentence-final word. In the applied reports, however, speech, when adopted, is often continuous and meaningful to participants. In contrast to the recent report [114], there has been an apparent down-trend in work manipulating the intelligibility of speech and the use of speech masking. Within the 2021–2023 period, some characteristics of background sound were considered of importance in both basic and applied research. This included intensity, albeit this was predominantly investigated within the applied reports. Sound pressure level, however, was inconsistently reported between studies and sometimes not reported at all, which is an area requiring improvement in future work. Aside from intensity, other acoustic characteristics such as its predictability or rhythmicity, or whether sound can be used as a cue for visual stimulus presentation, are only of interest to basic research. Applied research uses more plausible sounds.

As for the tasks adopted to investigate the impact of background sound, the visual-verbal serial recall task, and its variants, is still a favoured measure in both basic and applied research. Certainly, however, during the 2021–2023 period, studies used other cognitive tasks to investigate the impact of background sound on cognitive performance. While we support this expansion of the compass of research paradigms adopted beyond visual-verbal serial recall, we nevertheless express a degree of necessary caution: It is often the case, that the selection of a particular type of task lacked justification, beyond that it (often broadly) purportedly measured some core cognitive function (e.g., some aspect of attention or executive function) that, according to some studies, was a cornerstone of some higher cognitive faculty which would need to be drawn on for effective task performance within, for example, workplace settings. Arguably troublesome for such an approach is that the component processes of some tasks deployed have not been effectively characterised such that, from a theoretical perspective, the mechanism by which a task becomes vulnerable to disruption/facilitation via sound is unknown. In our view, this often leads to a redescription of the results or an underdeveloped theoretical account of reported data. Identifying the components of sound and of focal tasks that determine susceptibility to auditory distraction/facilitation that is key for basic research, nevertheless has implications for applied research. For example, finding that visual-*spatial* performance is invulnerable to the same distractors that impair visual-*verbal* performance, suggests the possibility that some workspaces are better suited to some cognitive performances than others. Moreover, a preoccupation of work using visual-verbal serial recall, for which cognitive performance is extremely sensitive to disruption via acoustic changes within background sound, could obscure efforts to understand the mechanisms through which disruption to non-seriation based tasks emerge. In other words, global recommendations for the acoustic optimisation of workspaces should not depend on results gleaned with a single task. Basic research suggests that the meaning of background sound lacks power to disrupt visual-verbal serial recall. At first glance, this would suggest that noise abatement policy should focus on reducing acoustic variability within a speech signal. However, other studies demonstrate that the semanticity of single-sentence utterances is important in determining disruption. Further other studies suggest that even in the absence of its influence on concurrent focal task performance, the semanticity of task-irrelevant sound can affect downstream cognition. These findings suggest reducing the acoustic variability and speech intelligibility of background sound should be targeted to maximally reduce its disruption. Since office tasks likely comprise a number of different cognitive processes, more research is required to investigate the impact of optimisation measures on a broader variety of cognitive processes (non-verbal e.g., visual-spatial, episodic, semantic).

As we have indicated before [114] there is a source of conflict between stances taken by proponents of basic research–who seek to understand and identify cognitive processes–and those applied researchers who are interested in whether auditory distraction effects can be "scaled up" and found with more complex tasks that have increased ecological validity for real workplace settings. The preoccupation with understanding the core processing components of a visual task and how they interact with auditory processing is perhaps difficult to grasp, or is deliberately, or unconsciously, omitted from the research agenda of applied psychologists. As alluded to previously, this issue may be circumvented somewhat by the design and construction of a standardised test battery that allows for the investigation of different varieties of noise effects on cognitive performance. Depending on the specifics of a research question, practitioners could draw upon the battery and perform a task analysis fitting for their target workplace.

As revealed by our two reviews [114, current review] that span six years (2017–2023), a plethora of basic and applied studies are continually being added to the research space concerning the impact of background noise on cognitive performance. While for the basic literature studies much of the research focuses on manipulations of different auditory characteristics within very well defined experimental paradigms, there is much less cohesion among the studies within the applied literature. Studies within the applied domain tend to use a wide variety of cognitive measures, sounds and testing environments. From the body of applied work, it is thus very difficult to answer the central question of cognitive noise research: which noise or which noise characteristics interfere with which cognitive functions and why? On the other hand, it is challenging to infer from the body of basic research studies to real-world cognitive performance in workplaces, given the generally complex and variable characteristics of both the cognitive tasks to be performed and the noise conditions encountered.

Acknowledgements

We would like to thank Melissa Gibbs (Research Assistant, University of Central Lancashire) and Luise Haehn and Tom Jungbauer (Research Assistants, RWTH Aachen University) for their support in the literature search, reducing the records and inspection of the selected reports. We would also like to express our gratitude to Dr Isabel Schiller (RWTH Aachen University) for her support in guiding the literature review, and to Clara Herbst in final formatting of text, tables, and references. The support provided by Gibbs was provided through internal funds awarded to Dr. John E. Marsh. Support provided by Haehn, Jungbauer, Herbst and Schiller, as well as the contribution of Jaqueline Gädtke was funded by a grant from the HEAD-Genuit-Stiftung (Head-Genuit Foundation; P-16/10-W) awarded to Prof. Dr. Sabine J. Schlittmeier. Dr John E. Marsh's contribution was supported by a grant received from the Bial Foundation (grant number 201/20).

REFERENCES

[1] Abbasi, A. M., Darvishi, E., Rodrigues, M. A., & Sayehmiri, K. (2022). Gender differences in cognitive performance and psychophysiological responses during noise exposure and different workloads. Applied Acoustics, 189, 108602. https://doi.org/10.1016/j.apacoust.2021.108602

[2] Alali-Morlevy, K., & Goldfarb, L. (2022). The effect of background sounds on mind

wandering. Psychological Research. https://doi.org/10.1007/s00426-022-01751-2

[3] Alikadic, L., & Röer, J. P. (2022). Loud auditory distractors are more difficult to ignore after all. Experimental Psychology, 69(3), 163–171. https://doi.org/10.1027/1618-3169/a000554

[4] Aloysius, N. M. F., Hamid, A. I. A., & Mustafar, F. (2023). Alpha and low gamma embedded with white noise binaural beats modulating working memory among malaysian young adult: A preliminary fMRI study. Malaysian Journal of Medicine and Health Sciences, 19(1), 113-124. https://doi.org/10.47836/mjmhs19.1.17

[5] Alyan, E., Saad, N. M., Kamel, N., Yusoff, M. Z., Zakariya, M. A., Rahman, M. A., Guillet, C., & Merienne, F. (2021). Frontal electroencephalogram alpha asymmetry during mental stress related to workplace noise. Sensors, 21(6), 1968. https://doi.org/10.3390/s21061968

[6] Aminian, O., Saraie, M., Ahadi, M., & Eftekhari, S. (2021). Association of the working environment noise with occupational stress in industrial workers. Journal of Public Health. https://doi.org/10.1007/s10389-021-01605-y

[7] An, S., Kim, K., Ahn, D., Lee, H., Son, M., & Beck, D. (2022). Effects of auditory pre-stimulation on cognitive task performance in a noisy environment. Applied Sciences, 12(12), 5823. https://doi.org/10.3390/app12125823

[8] Anandan, E. S., Husain, R., & Seluakumaran, K. (2021). Auditory attentional filter in the absence of masking noise. Attention, Perception, & Psychophysics, 83(4), 1737–1751. https://doi.org/10.3758/s13414-020-02210-z

[9] Ascone, L., Kling, C., Wieczorek, J., Koch, C., & Kühn, S. (2021). A longitudinal, randomized experimental pilot study to investigate the effects of airborne infrasound on human mental health, cognition, and brain structure. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-82203-6

[10] Awada, M., Becerik-Gerber, B., Lucas, G., & Roll, S. (2022). Cognitive performance, creativity and stress levels of neurotypical young adults under different white noise levels. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-022-18862-w

[11] Bell, R., Mieth, L., Röer, J. P., & Buchner, A. (2022). The metacognition of auditory distraction: Judgments about the effects of deviating and changing auditory distractors on cognitive performance. Memory & Cognition, 50, 160–173. https://doi.org/10.3758/s13421-021-01200-2

[12] Blain, S., Talamini, F., Fornoni, L., Bidet-Caulet, A., & Caclin, A. (2022). Shared cognitive resources between memory and attention during sound-sequence encoding. Attention, Perception, & Psychophysics, 84(3), 739–759. https://doi.org/10.3758/s13414-021-02390-2

[13] Blomberg, R., Johansson Capusan, A., Signoret, C., Danielsson, H., & Rönnberg, J. (2021). The effects of working memory load on auditory distraction in adults with attention deficit hyperactivity disorder. Frontiers in Human Neuroscience, 15. https://doi.org/10.3389/fnhum.2021.771711

[14] Daly, H. R., & Pitt, M. A. (2021). Distractor probability influences suppression in auditory selective attention. Cognition, 216, 104849. https://doi.org/10.1016/j.cognition.2021.104849

[15] Dámian-Chávez, M. M., Ledesma-Coronado, P. E., Drexel-Romo, M., Ibarra- Zárate, D. I., & Alonso-Valerdi, L. M. (2021). How does environmental noise impact collaborative activities at the main library of Tecnologico de Monterrey? 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC). https://doi.org/10.1109/embc46164.2021.9630265

[16] De Winne, J., Devos, P., Leman, M., & Botteldooren, D. (2022). With no attention specifically directed to it, rhythmic sound does not automatically facilitate visual task performance. Frontiers in Psychology, 13. https://doi.org/10.3389/fpsyg.2022.894366

[17] Di Battista, A., Price, A., Malkin, R., Drinkwater, B. W., Kuberka, P., & Jarrold, C. (2022). The effects of high-intensity 40 kHz ultrasound on cognitive function. Applied Acoustics, 200, 109051. https://doi.org/10.1016/j.apacoust.2022.109051

[18] ElShafei, H. A., Masson, R., Fakche, C., Fornoni, L., Moulin, A., Caclin, A., & Bidet-Caulet, A. (2022). Age-related differences in bottom-up and top-down attention: Insights from EEG and MEG. European Journal of Neuroscience, 55(5), 1215–1231. https://doi.org/10.1111/ejn.15617

[19] Elliott, E. M., Bell, R., Gorin, S., Robinson, N., & Marsh, J. E. (2022). Auditory distraction can be studied online! A direct comparison between in-person and online experimentation. Journal of Cognitive Psychology, 34(3), 307–324. https://doi.org/10.1080/20445911.2021.2021924

[20] Engelbregt, H., Barmentlo, M., Keeser, D., Pogarell, O., & Deijen, J. B. (2021). Effects of binaural and monaural beat stimulation on attention and EEG. Experimental Brain Research, 239(9), 2781–2791. https://doi.org/10.1007/s00221-021-06155-z

[21] Fallah Madvari, R., Zare Sakhvidi, M. J., Jafari Nodoushan, M., Askari, J., Fallahzadeh, H., & Raiszade Dashtaki, M. (2022). Effect of sound pressure levels on problem-solving abilities with the mediation of personality traits. Hearing, Balance and Communication, 1–7. https://doi.org/10.1080/21695717.2022.2142371

[22] Fu, V. X., Oomens, P., Kleinrensink, V. E., Sleurink, K. J., Borst, W. M., Wessels, P. E., Lange, J. F., Kleinrensink, G.-J., & Jeekel, J. (2020). The effect of preferred music on mental workload and laparoscopic surgical performance in a simulated setting (optimise): A randomized controlled crossover study. Surgical Endoscopy, 35(9), 5051–5061. https://doi.org/10.1007/s00464-020-07987-6

[23] Gao, M., Chang, R., Wang, A., Zhang, M., Cheng, Z., Li, Q., & Tang, X. (2021). Which can explain the pip-and-pop effect during a visual search: Multisensory integration or the oddball effect? Journal of Experimental Psychology: Human Perception and Performance, 47(5), 689–703. https://doi.org/10.1037/xhp0000905

[24] Georgi, M., Leist, L., Klatte, M., & Schlittmeier, S. J. (2022). Investigating the disturbance impact of background speech on verbal and visual-spatial short-term memory: On the differential contributions of changing-state and phonology to the irrelevant sound effect. Auditory Perception & Cognition, 1–20. https://doi.org/10.1080/25742442.2022.2127988

[25] Gheewalla, F., McClelland, A., & Furnham, A. (2020). Effects of background noise and extraversion on reading comprehension performance. Ergonomics, 64(5), 593–599. https://doi.org/10.1080/00140139.2020.1854352

[26] Golmohammadi, R., Darvishi, E., Shafiee Motlagh, M., & Faradmal, J. (2021). Role of individual and personality traits in occupational noise-induced psychological effects.

Applied Acoustics, 173, 107699. https://doi.org/10.1016/j.apacoust.2020.107699

[27] Guitard, D., & Saint-Aubin, J. (2021). The irrelevant speech effect in backward recall is modulated by foreknowledge of recall direction and response modality. Canadian Journal of Experimental Psychology, 75(3), 245-260. https://doi.org/10.1037/cep0000248

[28] Han, S., Zhu, R., & Ku, Y. (2021). Background white noise and speech facilitate visual working memory. European Journal of Neuroscience, 54(7), 6487-6496. https://doi.org/10.1111/ejn.15455

[29] Hao, H., & Conway, A. R. (2021). The impact of auditory distraction on reading comprehension: An individual differences investigation. Memory & Cognition, 50(4), 852–863. https://doi.org/10.3758/s13421-021-01242-6

[30] He, X., Liu, W., Qin, N., Lyu, L., Dong, X., & Bao, M. (2021). Performance-dependent reward hurts performance: The non-monotonic attentional load modulation on task-irrelevant distractor processing. Psychophysiology, 58(12). https://doi.org/10.1111/psyp.13920

[31] Huda, L. N., Salsabila, C., & Nasution, I. (2021). The effect of noise on average beta EEG signal. 2021 5th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM). https://doi.org/10.1109/elticom53303.2021.9590112

[32] Jalali, M., Ebrahemzadih, M., Reza Zakeri, H., Farhadi, S., Sajedifar, J., & Abd Mojiri, S. (2022). The relationship between noise exposure, fatigue and subjective mental workload. SIGURNOST, 64(3), 259 – 269. https://doi.org/10.31306/s.64.3.4

[33] Jeon, J. Y., Jo, H. I., Santika, B. B., & Lee, H. (2022). Crossed effects of audio-visual environment on indoor soundscape perception for pleasant open-plan office environments. Building and Environment, 207, 108512. https://doi.org/10.1016/j.buildenv.2021.108512

[34] Jo, H. I., & Jeon, J. Y. (2022a). Influence of indoor soundscape perception based on audiovisual contents on work-related quality with preference and perceived productivity in open-plan offices. Building and Environment, 208, 108598. https://doi.org/10.1016/j.buildenv.2021.108598

[35] Jo, H. I., Santika, B. B., Lee, H., & Jeon, J. Y. (2022b). Classification of sound environment based on subjective response with speech privacy in open plan offices. Applied Acoustics, 189, 108595. https://doi.org/10.1016/j.apacoust.2021.108595

[36] Kattner, F. (2021). Transfer of working memory training to the inhibitory control of auditory distraction. Psychological Research, 85(8), 3152–3166. https://doi.org/10.1007/s00426-020-01468-0

[37] Kattner, F., & Bryce, D. (2022a). Attentional control and metacognitive monitoring of the effects of different types of task-irrelevant sound on serial recall. Journal of Experimental Psychology: Human Perception and Performance, 48(2), 139–158. https://doi.org/10.1037/xhp0000982

[38] Kattner, F., Hanl, S., Paul, L., & Ellermeier, W. (2022b). Task-specific auditory distraction in serial recall and mental arithmetic. Memory & Cognition, 51(4), 930–951. https://doi.org/10.3758/s13421-022-01363-6

[39] Kattner, F., Richardson, B. H., & Marsh, J. E. (2022c). The benefit of foreknowledge in auditory distraction depends on the intelligibility of pre-exposed speech. Auditory Perception & Cognition, 5(3-4), 151-168. https://doi.org/10.1080/25742442.2022.2089525

[40] Ke, J., Du, J., & Luo, X. (2021a). The effect of noise content and level on cognitive performance measured by electroencephalography (EEG). Automation in Construction, 130. https://doi.org/10.1016/j.autcon.2021.103836

[41] Ke, J., Zhang, M., Luo, X., & Chen, J. (2021b). Monitoring distraction of construction workers caused by noise using a wearable electroencephalography (EEG) device. Automation in Construction, 125, 103598. https://doi.org/10.1016/j.autcon.2021.103598

[42] Kennedy-Metz, L. R., Arshanskiy, M., Keller, S., Arney, D., Dias, R. D., & Zenati, M. A. (2022). Association between operating room noise and team cognitive workload in cardiac surgery. 2022 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA). https://doi.org/10.1109/cogsima54611.2022.9830675

[43] Kim, A. J., Lee, D. S., & Anderson, B. A. (2021). Previously reward-associated sounds interfere with goal-directed auditory processing. Quarterly Journal of Experimental Psychology, 74(7), 1257–1263. https://doi.org/10.1177/1747021821990033

[44] Kolbeinsson, Ö., Asutay, E., Wallqvist, J., & Hesser, H. (2022). Prior information can alter how sounds are perceived and emotionally regulated. Heliyon, 8(6). https://doi.org/10.1016/j.heliyon.2022.e09793

[45] Krasich, K., Kim, J., Huffman, G., Klaffehn, A. L., & Brockmole, J. R. (2021). Does task-irrelevant music affect gaze allocation during real-world scene viewing? Psychonomic Bulletin & Review, 28(6), 1944–1960. https://doi.org/10.3758/s13423-021-01947-4

[46] Lagarrigue, Y., Cappe, C., & Tallet, J. (2021). Regular rhythmic and audio-visual stimulations enhance procedural learning of a perceptual-motor sequence in healthy adults: A pilot study. PLOS ONE, 16(11). https://doi.org/10.1371/journal.pone.0259081

[47] Leist, L., Breuer, C., Yadav, M., Fremerey, S., Fels, J., Raake, A., Lachmann, T., Schlittmeier, S. J., & Klatte, M. (2022a). Differential effects of task-irrelevant monaural and binaural classroom scenarios on children's and adults' speech perception, listening comprehension, and visual–verbal short-term memory. International Journal of Environmental Research and Public Health, 19(23), 15998. https://doi.org/10.3390/ijerph192315998

[48] Leist, L., Lachmann, T., Schlittmeier, S. J., Georgi, M., & Klatte, M. (2022b). Irrelevant speech impairs serial recall of verbal but not spatial items in children and adults. Memory & Cognition, 51(2), 307–320. https://doi.org/10.3758/s13421-022-01359-2

[49] Leiva, A., Andrés, P., & Parmentier, F. B. (2021). Aging increases cross-modal distraction by unexpected sounds: Controlling for response speed. Frontiers in Aging Neuroscience, 13. https://doi.org/10.3389/fnagi.2021.733388

[50] Lim, W., Furnham, A., & McClelland, A. (2021). Investigating the effects of background noise and music on cognitive test performance in introverts and extraverts: A cross-cultural study. Psychology of Music, 50(3), 709–726. https://doi.org/10.1177/03057356211013502

[51] Littlefair, Z., Vachon, F., Ball, L. J., Robinson, N., & Marsh, J. E. (2022). Acoustic, and categorical, deviation effects are produced by different mechanisms: Evidence from additivity and habituation. Auditory Perception & Cognition, 5(1-2), 1-24. https://doi.org/10.1080/25742442.2022.2063609

[52] Love, J., Sung, W., & Francis, A. L. (2021). Psychophysiological responses to potentially annoying heating, ventilation, and air conditioning noise during mentally demanding work. The Journal of the Acoustical Society of America, 150(4), 3149–3163. https://doi.org/10.1121/10.0006383

[53] Luo, J., Wang, M., & Chen, L. (2021). The effects of using a nature-sound mobile application on psychological well-being and cognitive performance among university students. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.699908

[54] Luo, J., Wang, M., Chen, B., & Sun, M. (2022). Exposure to nature sounds through a mobile application in daily life: Effects on learning performance among university students. International Journal of Environmental Research and Public Health, 19, 14583. https://doi.org/10.3390/ijerph192114583

[55] Manghisi, V. M., Martellotta, F., Evangelista, A., Giliberti, C., Mariconte, R., Diano, M., Galasso, V., & Uva, A. E. (2022). Investigating the effects on user performance and perceived workload of environmental noise in immersive virtual reality. 2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE). https://doi.org/10.1109/metroxraine54828.2022.9967541

[56] Marcenaro, B., Leiva, A., Dragicevic, C., López, V., & Delano, P. H. (2021). The medial olivocochlear reflex strength is modulated during a visual working memory task. Journal of Neurophysiology, 125(6), 2309–2321. https://doi.org/10.1152/jn.00032.2020

[57] Marsh, J. E., Vachon, F., Sörqvist, P., Marsja, E., Röer, J. P., Richardson, B. H., & Ljungberg, J. K. (2023). Irrelevant changing-state vibrotactile stimuli disrupt verbal serial recall: Implications for theories of interference in short-term memory. Journal of Cognitive Psychology. https://doi.org/10.1080/20445911.2023.2198065

[58] Masullo, M., Ruggiero, G., Alvarez Fernandez, D., Iachini, T., & Maffei, L. (2021a). Effects of urban noise variability on cognitive abilities in indoor spaces: Gender differences. Noise & Vibration Worldwide, 52(10), 313–322. https://doi.org/10.1177/09574565211030703

[59] Masullo, M., Toma, R. A., Pascale, A., Ruggiero, G., & Maffei, L. (2021b). Different effects of cognitive load on overhead crane operators in a virtual reality simulator. Proceedings of the Third Symposium on Psychology-Based Technologies (PSYCHOBIT2021).

[60] Meinhardt-Injac, B., Imhof, M., Wetzel, N., Klatte, M., & Schlittmeier, S. J. (2022). The irrelevant sound effect on serial recall is independent of age and inhibitory control. Auditory Perception & Cognition, 5(1–2), 25–45. https://doi.org/10.1080/25742442.2022.2064692

[61] Meng, Q., An, Y., & Yang, D. (2021) Effects of acoustic environment on design work performance based on multitask visual cognitive performance in office space. Building and Environment, 205. https://doi.org/10.1016/j.buildenv.2021.108296

[62] Monazzam Esmaielpour, M. R., Zakerian, S. A., Abbasi, M., Ábbasi Balochkhaneh, F.,

& Mousavi Kordmiri, S. H. (2021). Investigating the effect of noise exposure on mental disorders and the work ability index among industrial workers. Noise & Vibration Worldwide, 53(1-2), 3–11. https://doi.org/10.1177/09574565211052690

[63] Mones, P., & Massonnié, J. (2022). What can you do with a bottle and a hanger? Students with high cognitive flexibility give more ideas in the presence of ambient noise. Thinking Skills and Creativity, 46, 101116. https://doi.org/10.1016/j.tsc.2022.101116

[64] Mueller, B. J., Liebl, A., Herget, N., Kohler, D., & Leistner, P. (2022). Using active noise-cancelling headphones in open-plan offices: No influence on cognitive performance but improvement of perceived privacy and acoustic environment. Frontiers in Built Environment, 8. https://doi.org/10.3389/fbuil.2022.962462

[65] Nagaraj, N. K. (2021). Effect of auditory distraction on working memory, attention switching, and listening comprehension. Audiology Research, 11(2), 227–243. https://doi.org/10.3390/audiolres11020021

[66] Niazmand-Aghdam, N., Ranjbarian, M., Khodakarim, S., Mohammadian, F., & Dehghan, S. F. (2021). The effects of combined exposure to road traffic noise and whole body vibration on types of attention among men. La Medicina del Lavoro, 112(5), 360-369. https://doi.org/10.23749/mdl.v112i5.11772

[67] Parmentier, F. B., Leiva, A., Andrés, P., & Maybery, M. T. (2022). Distraction by violation of sensory predictions: Functional distinction between deviant sounds and unexpected silences. PLOS ONE, 17(9). https://doi.org/10.1371/journal.pone.0274188

[68] Pascoe, A. J., Haque, Z. Z., Samandra, R., Fehring, D. J., & Mansouri, F. A. (2022). Dissociable effects of music and white noise on conflict-induced behavioral adjustments. Frontiers in Neuroscience, 16. https://doi.org/10.3389/fnins.2022.858576

[69] Pedale, T., Mastroberardino, S., Capurso, M., Bremner, A. J., Spence, C., & Santangelo, V. (2021). Crossmodal spatial distraction across the lifespan. Cognition, 210, 104617. https://doi.org/10.1016/j.cognition.2021.104617

[70] Pérez-Bellido, A., Spaak, E., & de Lange, F. P. (2023). Magnetoencephalography recordings reveal the neural mechanisms of auditory contributions to improved visual detection. Communications Biology, 6(1). https://doi.org/10.1038/s42003-022-04335-3

[71] Pérez-Hernández, M., Hernández-González, M., Hidalgo-Aguirre, R. M., Guevara, M. A., Amezcua-Gutiérrez, C., & Sandoval-Carrillo, I. K. (2021) Multiparity decreases the effect of distractor stimuli on a working memory task: An EEG study. Social Neuroscience, 16(3), 277-288. https://doi.org/10.1080/17470919.2021.1899048

[72] Perham, N., Begum, F., & Marsh, J. E. (2023). The categorical deviation effect may be underpinned by attentional capture: Preliminary evidence from the incidental recognition of distracters. Auditory Perception & Cognition, 1-32. https://doi.org/10.1080/25742442.2023.2167448

[73] Pieper, K., Spang, R. P., Prietz, P., Möller, S., Paajanen, E., Vaalgamaa, M., & Voigt-Antons, J.-N. (2021). Working with environmental noise and noise-cancelation: A workload assessment with EEG and subjective measures. Frontiers in Neuroscience 15, 771533. https://doi.org/10.3389/fnins.2021.771533

[74] Prutean, N., Wenk, T., Leiva, A., Vaquero, J. M., Lupiáñez, J., & Jiménez, L. (2022). Cognitive control modulates the expression of implicit sequence learning: Congruency

sequence and oddball-dependent sequence effects. Journal of Experimental Psychology: Human Perception and Performance, 48(8), 842–855. https://doi.org/10.1037/xhp0001025

[75] Radun, J., Maula, H., Rajala, V., Scheinin, M., & Hongisto, V. (2020). Speech is special: The stress effects of speech, noise, and silence during tasks requiring concentration. Indoor Air, 31, 264-274. https://doi.org/10.1111/ina.12733

[76] Radun, J., Maula, H., Rajala, V., Scheinin, M., & Hongisto, V. (2022). Acute stress effects of impulsive noise during mental work. Journal of Environmental Psychology, 81, 101819. https://doi.org/10.1016/j.jenvp.2022.101819

[77] Rahmani, R., Aliabadi, M., Golmohammadi, R., Babamiri, M., & Farhadian, M. (2021). Evaluation of cognitive performance of city bus drivers with respect to noise and vibration exposure. Acoustics Australia, 49, 529-539. https://doi.org/10.1007/s40857-021-00248-z

[78] Rakhshan, V., Hassani-Abharian, P., Joghataei, M., Nasehi, M., & Khosrowabadi, R. (2022). Effects of the alpha, beta, and gamma binaural beat brain stimulation and short-term training on simultaneously assessed visuospatial and verbal working memories, signal detection measures, response times, and intrasubject response time variabilities: A within-subject randomized placebo-controlled clinical trial. BioMed Research International, 2022, 1–42. https://doi.org/10.1155/2022/8588272

[79] Richardson, B., McCulloch, K. C., Ball, L. J., & Marsh, J. E. (2022). The fate of the unattended revisited: Can irrelevant speech prime the non-dominant interpretation of homophones? Auditory Perception & Cognition, 6(1-2), 72-96. https://doi.org/10.1080/25742442.2022.2124799

[80] Ríos-López, P., Widmann, A., Bidet-Caulet, A., & Wetzel, N. (2021). The effect of background speech on attentive sound processing: A pupil dilation study. PsyArXiv. https://doi.org/10.31234/osf.io/c6mju

[81] Röer, J. P., Bell, R., Buchner, A., Saint-Aubin, J., Sonier, R.-P., Marsh, J. E., Moore, S. B., Kershaw, M. B., Ljung, R., & Arnström, S. (2022). A multilingual preregistered replication of the semantic mismatch effect on serial recall. Journal of Experimental Psychology: Learning, Memory, and Cognition, 48(7), 966–974. https://doi.org/10.1037/xlm0001066

[82] Sadeghian, M., Mohammadi, Z., & Mousavi, S. M. (2021). Investigation of electroencephalography variations of mental workload in the exposure of the psychoacoustic in both male and female groups. Cognitive Neurodynamics, 16(3), 561–574. https://doi.org/10.1007/s11571-021-09737-3

[83] Salagovic, C. A., & Leonard, C. J. (2020). A nonspatial sound modulates processing of visual distractors in a flanker task. Attention, Perception, & Psychophysics, 83(2), 800–809. https://doi.org/10.3758/s13414-020-02161-5

[84] Samper, J. R., Morrison, A., & Chein, J. (2021). Doubts about the role of rehearsal in the irrelevant sound effect. Experimental Psychology, 68(5), 229–242. https://doi.org/10.1027/1618-3169/a000527

[85] Sander, E., J, Marques, C., Birt, J., Stead, M., & Baumann, O. (2021). Open-plan office noise is stressful: Multimodal stress detection in a simulated work environment. Journal of Management & Organization, 27(6), 1021–1037. https://doi.org/10.1017/jmo.2021.17

[86] Schäffer, B., Taghipour, A., Wunderli, J. M., Brink, M., Bartha, L., & Schlittmeier, S. J. (2022). Does the macro-temporal pattern of road traffic noise affect noise annoyance and cognitive performance? International Journal of Environmental Research and Public Health, 19(7), 4255. https://doi.org/10.3390/ijerph19074255

[87] Schirmer, A., Wijaya, M., Chiu, M. H., Maess, B., & Gunter, T. C. (2020). Musical rhythm effects on visual attention are non-rhythmical: Evidence against metrical entrainment. Social Cognitive and Affective Neuroscience, 16(1-2), 58–71. https://doi.org/10.1093/scan/nsaa077

[88] Sheikhmozafari, M. J., Mohammad Alizadeh, P., Ahmadi, O., Mazloomi, B. (2021). Assessment of noise effect on employee comfort in an open-plan office: Validation of an assessment questionnaire. Journal of Occupational Health and Epidemiology, 10(3), 193-203. https://doi.org/10.52547/johe.10.3.193

[89] Shibuya, Y., Yanagisawa, K., & Kajimura, S. (2022). Effects of adaptive sound level changes of background music on cognitive tasks. 2022 IEEE 11th Global Conference on Consumer Electronics (GCCE). https://doi.org/10.1109/gcce56475.2022.10014263

[90] Shkembi, A., Smith, L. M., Le, A. B., & Neitzel, R. L. (2022). Noise exposure and mental workload: Evaluating the role of multiple noise exposure metrics among surface miners in the US midwest. Applied Ergonomics, 103, 103772. https://doi.org/10.1016/j.apergo.2022.103772

[91] Simal, A., & Jolicoeur, P. (2021). Cortical activation by a salient sound modulates visual temporal order judgments: An electrophysiological study of multisensory attentional processes. Psychophysiology, 59(1). https://doi.org/10.1111/psyp.13943

[92] Soh, C., & Wessel, J. R. (2020). Unexpected sounds nonselectively inhibit active visual stimulus representations. Cerebral Cortex, 31(3), 1632–1646. https://doi.org/10.1093/cercor/bhaa315

[93] Song, C., Li, H., Ma, H., Han, T., & Wu, J. (2022). Effects of noise type and noise sensitivity on working memory and noise annoyance. Noise Health, 24(114), 173-181. https://doi.org/10.4103/nah.nah_6_22

[94] Stobbe, E., Sundermann, J., Ascone, L., & Kühn, S. (2022). Birdsongs alleviate anxiety and paranoia in healthy participants. Scientific Reports, 12, 16414. https://doi.org/10.1038/s41598-022-20841-0

[95] Sugimoto, F., Kimura, M., & Takeda, Y. (2022). Investigation of the optimal time interval between task-irrelevant auditory probes for evaluating mental workload in the shortest possible time. International Journal of Psychophysiology, 177, 103–110. https://doi.org/10.1016/j.ijpsycho.2022.04.013

[96] Szychowska, M., & Wiens, S. (2021). Visual load effects on the auditory steady-state responses to 20-, 40-, and 80-Hz amplitude-modulated tones. Physiology & Behavior, 228, 113240. https://doi.org/10.1016/j.physbeh.2020.113240

[97] Teodoro, T., Koreki, A., Chen, J., Coebergh, J., Poole, N., Ferreira, J. J., Edwards, M. J., & Isaacs, J. D. (2022). Functional cognitive disorder affects reaction time, subjective mental effort and global metacognition. Brain, 146(4), 1615–1623. https://doi.org/10.1093/brain/awac363

[98] Tseng, L. P., Chuang, M. T., & Liu, Y. C. (2022) Effects of noise and music on situation

awareness, anxiety, and the mental workload of nurses during operations. Applied Ergonomics, 99. https://doi.org/10.1016/j.apergo.2021.103633

[99] Turoman, N., Tivadar, R. I., Retsa, C., Murray, M. M., & Matusz, P. J. (2021). Towards understanding how we pay attention in naturalistic visual search settings. NeuroImage, 244, 118556. https://doi.org/10.1016/j.neuroimage.2021.118556

[100] Wang, W., Fan, L., Wang, Z., Liu, X., & Zhang, S. (2021). Effects of phonological loop on inferential processing during Chinese text reading: Evidence from a dual-task paradigm. PsyCh Journal, 10(4), 521-533. https://doi.org/10.1002/pchj.451

[101] Wang, X., Lu, H., He, Y., Sun, K., Feng, T., & Zhu, X. (2022). Listening to 15 Hz binaural beats enhances the connectivity of functional brain networks in the mental fatigue state—an EEG study. Brain Sciences, 12(9), 1161. https://doi.org/10.3390/brainsci12091161

[102] Wang, A., Qian, Q., Zhao, C., Tang, X., & Zhang, M. (2021). Modal-based attention modulates attentional blink. Attention, Perception, & Psychophysics, 84(2), 372–382. https://doi.org/10.3758/s13414-021-02413-y

[103] Wang, L., Zhang, W., Li, X., & Yang, S. (2022). The effect of 40 Hz binaural beats on working memory. IEEE Access, 10, 81556–81567. https://doi.org/10.1109/access.2022.3185257

[104] Ward, E. V., Isac, A., Donnelly, M., Van Puyvelde, M., & Franco, F. (2021). Memory improvement in aging as a function of exposure to mood-matching music. Acta Psychologica, 212, 103206. https://doi.org/10.1016/j.actpsy.2020.103206

[105] Weichenberger, M., Bug, M. U., Brühl, R., Ittermann, B., Koch, C., & Kühn, S. (2022). Air-conducted ultrasound below the hearing threshold elicits functional changes in the cognitive control network. PLOS ONE, 17(12). https://doi.org/10.1371/journal.pone.0277727

[106] Whiting, W. L., & Murdock, K. K. (2021). Notification alert! Effects of auditory text alerts on attention and heart rate variability across three developmental periods. Quarterly Journal of Experimental Psychology, 74(11), 1900–1913. https://doi.org/10.1177/17470218211041851

[107] Yang, C., Pang, L., Liang, J., Cao, X., Fan, Y., & Zhang, J. (2022). Experimental investigation of task performance and human vigilance in different noise environments. Applied Sciences, 12(22), 11376. https://doi.org/10.3390/app122211376

[108] Yang, X., Spangler, D. P., Thayer, J. F., & Friedman, B. H. (2021). Resting heart rate variability modulates the effects of concurrent working memory load on affective startle modification. Psychophysiology, 58(8). https://doi.org/10.1111/psyp.13833

[109] Ylinen, A., Wikman, P., Leminen, M., & Alho, K. (2022). Task-dependent cortical activations during selective attention to audiovisual speech. Brain Research, 1775, 147739. https://doi.org/10.1016/j.brainres.2021.147739

[110] Yoo, G. E., Lee, S., Kim, A. J., Choi, S. H., Chong, H. J., & Park, S. (2022). Differential background music as attentional resources interacting with cognitive control. International Journal of Environmental Research and Public Health, 19(22), 15094. https://doi.org/10.3390/ijerph192215094

[111] Zhang, Y., Ou, D., Chen, Q., Kang, S., & Qu, G. (2022). The effects of indoor plants and

traffic noise on English reading comprehension of Chinese university students in home offices. Frontiers in Psychology, 13. https://doi.org/10.3389/fpsyg.2022.1003268

[112] Zhao, S., Li, Y., Wang, C., Feng, C., & Feng, W. (2021). Updating the dual-mechanism model for cross-sensory attentional spreading: The influence of space-based visual selective attention. Human Brain Mapping, 42(18), 6038-6052. https://doi.org/10.1002/hbm.25668

[113] Zhou, H., Molesworth, B. R. C., Burgess, M., & Hatfield, J. (2022) The effect of broadband noise on learning and dynamic decision-making and how cognitive workload and sex moderate its effect. Applied Ergonomics, 98. https://doi.org/10.1016/j.apergo.2021.103604

[114] Schlittmeier, S. J., & Marsh, J. E. (2021). Review of research on the effects of noise on cognitive performance 2017-2021. Proceedings of the 13th ICBEN Congress on Noise as a Public Health Problem. Retrieved May 31st, 2023, from: http://www.icben.org/2021/ICBEN%202021%20Papers/full_ paper_ 28062.pdf

[115] PRISMA (2020). PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only. Retrieved from http://prisma-statement.org/prismastatement/flowdiagram.aspx on 31 May 2023.

Table 1: Overview of Applied Research Studies

Author	[5] Alyan et al. (2021)	[6] Aminian et al. (2021)	[7] An et al. (2022)
Sample	18 male participants (27.2 ± 2.8 years old)	401 male workers from an industrial company (38.5 ± 7.8 years old, range 23-61 years)	24 healthy adults (11 males, mean age: 24.4 years, range 21-29, SD=2.1)
Result	Performance significantly decreased and physiological stress (measured by sAA) increased in the noise condition compared to the quiet condition. More attentional resources had to be allocated for selective attention during the noise condition, as suggested by decreased alpha power and a shift in frontal alpha-asymmetry (FAA)	Working in areas equal or above 85dBA significantly affected workers' workplace demands, as measured by COPSOQ' domain 1. However, no significant association with increased stress symptoms or decreased job satisfaction were found	Field-noise did not affect performance in two of the WM tasks (digit-span task & Corsi block-tapping task), only the digit span task. Performance in this task under field noise was improved when mixed noise was used as an auditory pre-stimulation, suggesting cancelling or recovering from the adverse impact of noise on phonological WM tasks
Sound Quality	Two noise conditions: quiet vs noisy workplace, noise stimuli = e.g., paper printing, moving furniture, telephone ringing	Company areas divided into noise below 85 dBA (154 (38.4%) of the workers) and equal or above 85 dBA (247 (61.6%) of the workers)	Experiment 1: Condition 1) Quiet-noise Environment (EQ) without auditory pre-stimulation (PN); Condition 2) Field-noise Environment (EF) without auditory pre-stimulation (PN); Experiment 2: Condition 3) Field-noise Environment (EF) with the auditory pre-stimulation of Quiet noise (PQ); Condition 4) Field-noise Environment (EF) with the auditory pre-stimulation of White noise (PW); Condition 5) Field-noise Environment (EF) with auditory pre-stimulation of Field noise (PF); Condition 6) Field-noise Environment (EF) with auditory pre-stimulation of Mixed noise (PM)
Level	Noise stressors: 64.4 -76.8 dB, mean = 70.6 dB	Range of noise measured in company: 44 to 115 dBA	EQ & PQ: 40~45 dBA; EF & PF: 80 dBA, PW: 60dBA; PM: 80dBA
Workplace	Open plan office (OPO) simulated	Industrial company	
Performance	MIST: Montreal Imaging Stress Task using the mental arithmetic task (MAT)		3 STM/WM tasks were the Corsi block-tapping, Digit span, and 3-back tasks
Task Load	Time constraints and immediate feedback of performance implemented to increase stress levels	No performance measured	Additionally collected mental workload ratings using visual analogue scales
Annoyance			
Distraction	Two noise conditions		
Perceived Disturbance		Copenhagen Psychosocial Questionnaire (COPSOQ) administered to determine psychosocial status and occupational stress levels of the employees	
Additional Information*	16-channel EEG and salivary alpha-amylase (sAA, indirect measure of sympathetic activation) measured		

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[10] Awada et al. (2022)	[21] Fallah Madvari et al. (2022)	[22] Fu et al. (2020)	[26] Golmohammadi et al. (2021)
Sample	40 university students (16 female, 25.82 ± 7.53 years old)	40 participants (17 male, 25.1 ± 3.19 years old, range 20-30 years)	97 medical students (42 male, median age 20 years, IQR 18 to 21 years)	31 male students (30.19 ± 6.6 years old)
Result	Compared to ambient office noise, stimulation with 45dB white noise improved cognitive performance, creativity, and decreased physiological stress responses as measured by EDA. Compared to the other sound conditions, stimulation with 65dB white noise improved working memory performance, meanwhile it also increased physiological stress responses, suggesting optimal noise levels for different executive functions and cognitive demand levels	Cognitive performance (problem-solving abilities) decreased with increasing SPLs. There is no relationship between personality traits and cognitive performance under differing SPLs	There was no significant difference between the open-plan (OP)-noise condition and the own-music condition in regard to the performance measure (performance in simulated laparoscopy). However, there was a significant difference of reduced mental workload in favour of the own-music condition, as well as lowered HR and increased HRV, suggesting preferred music reduced mental workload and surgical stressors	With increasing SPL levels, annoyance, fatigue, and subjective workload assessment increases as well. Age, general health status, noise sensitivity, and neuroticism are moderators of the psychological effect of noise
Sound Quality	Three sound conditions: white noise at 45 dB vs. white noise at 65 dB vs. ambient noise (background office noise, 42.3 ± 1.2 dB)	Industrial noise (recorded at textile mills factory) presented at four different SPL's	Two noise conditions: operation background noise only vs favourite music of participant	Five sound conditions: 1) quiet conditions (QC), 2) closed offices (CO), 3) open plan offices (OPO), 4) control rooms (CR), and 5) industrial workplaces (IW)
Level		33, 75, 85 and 95 dBA		1) QC: 54 ± 0.6 dBA, 2) CO: 64 ± 0.4 dBA; 3) OPO: 68 ± 0.8 dBA 4) CR: 73 ± 0.3 dBA; 5) IW: 80 ± 0.1 dBA
Workplace	OPO		Simulated operation room	
Performance	Continuous performance test (attention), Stroop test (inhibition, learning), 2-back test (memory), remote associate test (creativity), Typing performance test (speed and accuracy of work)	Problem-solving abilities assessed using the London Tower test	Laparoscopic task performance measured using laparoscopic box simulator via the peg transfer task	Cognitive tests during noise exposure, not specified further
Task Load			Mental workload assessed using SURG-TLX, version of NASA-TLX	Mental working load assessed using NASA-TLX
Annoyance				Annoyance assessed using numerical scale (ISO/TS 15666:2003), scale 1-100
Distraction	Sound conditions	Sound conditions		
Perceived Disturbance				Noise induced subjective fatigue levels assessed using visual analogue scale (VAS), scale 1-100
Additional Information*	Electrodermal activity (EDA) measured	Personality type assessed using Eysenck Personality Questionnaire	Heart rate and Heart Rate Variability (HRV) measured	General health and individual and personality traits assessed (General Health Questionnaire [GHQ], noise sensitivity [NS] of Weinstein, Beck Anxiety Inventory [BAI], Neuroticism-Extraversion-Openness Personality Inventory [NEO-PI])

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[32] Jalali et al. (2022)	[33] Jeon et al. (2022)	[34] Jo et al. (2022a)	[35] Jo et al. (2022b)
Sample	113 bank employees (38.41 ± 7.06 years old, range 24-56 years)	34 subjects (24.85 ± 3.56 years old, range 20-33 years), all subjects have experience with working in office environment (see [34])	Exp. 1) 34 subjects (24.85 ± 3.56 years old, range 20-33 years); Exp. 2) 41 subjects (18 females, 23.12 ± 2.82 years old, range 20-29 years), all subjects have experience with working in office environment	37 subjects (8 female, 23.41 ± 3.56 years old, range 18-31 years), all subjects have experience with working in office environment
Result	With increasing average LAeq, the ratings for mental workload, fatigue, and sensitivity to noise increase for bank employees, suggesting increased neurophysiological strains due to noise exposure	Physical sound indices of the office were only related to the auditory subjective ratings, but not for the visual ratings, while the visual indices were significantly related to the auditory subjective ratings, suggesting a cross-over effect	Exp. 1) With increasing SPL, the auditory complexity ratings increased as well, while satisfaction ratings and work performance decreased linearly and asymptotically, respectively. With increasing visual complexity, work performance and subjective satisfaction ratings decreased. Exp. 2) subjects accurately identified speech-related sound occurrences, but not others. Subjective ratings can be described on four dimensions for preferred vs. productive zones: comfort and content resp.	Dimension "Satisfaction" correlates positively with the spatial decay rate of speech (D2,S) and the ratio of energy until 50 ms after reaching the direct sound to the total energy (D50). It correlates negatively with the A-weighted SPL at a distance of 4 m from the sound source (Lp,A,S,4m) and the reverberation time. There is no significant association with the distraction distance (rD) is observed. Annoyance ratings show the opposite effect. Lp,A,S,4m has the biggest influence on satisfaction in an OPO
Sound Quality	Average noise exposure determined for bank employees at their working stations	Background noise recorded in open plan office (OPO), convolved with acoustic model of OPO, speech sounds sources convolved (see [34])	Background noise recorded in OPO, convolved with acoustic model of OPO, speech sounds sources convolved, Exp. 2) additionally OPO sounds manipulated (e.g., conversations, desk noise, printers, walking, ...)	Background noise recorded in OPO, convolved with acoustic model of OPO, speech sounds sources convolved
Level	Average LAeq at workstation is 61.30 dBA (6.41), ranging between50 and 76 dBA	three levels (LAeq): low = 45.9 dB, middle = 51.1 dB, high = 55.9 dB (see [34])	Exp. 1) three levels (LAeq) : low = 45.9 dB, middle = 51.1 dB, high = 55.9 dB; Exp. 2) 12 audio stimuli	Background noise (47dB) convoluted with 12 speech conditions with differing SNRs = -0.7 dB (case 1), 0 dB (2), 2.3 dB (3), -0.4 dB (4), 0.7 dB (5), 4.3 dB (6), -1.1 dB (7), 0.9 dB (8), 4.1 dB (9), -0.3 dB (10), 1.8 dB (11), and 8.9 dB (12)
Workplace	Bank	OPO simulated	OPO simulated	OPO simulated
Performance	No performance measures	Backward digit span task (see [34])	Exp. 1) backward digit span task; Exp. 2) noise source identification	
Task Load	NASA-TLX			
Annoyance	Fatigue measured using SOFI-20		Satisfaction rated	Questionnaire evaluating six sound ratings: willingness, annoyance, privacy, immersion, pleasantness, and comfort
Distraction				Background sounds
Perceived Disturbance	Noise sensitivity via Weinstein questionnaire			
Additional Information*		VR study: simulated OPO layouts differing in sizes, interiors, worker capacities and window layouts (see [34]). Visual and auditory stimuli subjectively rated for auditory (Loud, Variable, Reverberant) and visual (Bright, Orderly, Wide) attributes, preference, privacy, and work	VR study: simulated OPO layouts differing in sizes, interiors, worker capacities and window layouts. Visual and auditory stimuli subjectively rated for e.g., complexity of environment, overall satisfaction, perceived productivity, willingness to work	Collected information about noise sensitivity

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[40] Ke et al. (2021a)	[41] Ke et al. (2021b)	[42] Kennedy-Metz et al. (2022)
Sample	27 university students (4 females, range 18-25 years)	27 university students (4 females, range 18-25 years)	18 non-emergent cardiac surgeries with n = 16 staff members performing the procedure
Result	Lower performance in accuracy and reaction times under noise conditions	No significant impact of noise on behavioural performance; SVM classifier was able to distinguish between "focused" and "distracted" states with high accuracy using information of the theta and gamma band in temporal and prefrontal areas	High-noise segments were associated with increased Team HR and more case-irrelevant communication compared to low-noise segments, suggesting increased team-wide cognitive workload levels during high-noise segments
Sound Quality	Six sound conditions: no noise (CG), music (pop songs) (MUG), speech (DG), low mechanical noise (LMG), medium mechanical noise (MMG), and high mechanical noise (HMG)	Two sound conditions: no background noise vs construction site noise	Sound recordings of cardiac surgery procedure, 18 low- and high-noise 5-minute segments identified, respectively
Level	CG, MUG, DG, MMG = 70dBA, LMG = 60 dB, HMG = 80dB	Noise condition: 80dB	Low-noise segments = segments with zero peaks in noise above 70 dBA; high-noise segments = segments with highest percentage of peaks in noise above 70 dBA
Workplace	Simulated construction site in lab	simulated construction site in lab	Operation room
Performance	Identification of potentially hazardous wall/floor openings on a construction site with concurrent noise stimulation, accuracy of identification and reaction time measured	Identification of potentially hazardous wall/floor openings on a construction site; accuracy of identification and correct location, as well as reaction time measured	No cognitive performance measures assessed
Task Load			Team Heart rate (Team HR) assessed based on normalised individual HR before, during, and after segment of interest (low noise vs. high noise); and nature and duration of communication events categorised (events: case-relevant, case-irrelevant, or no communication)
Annoyance			
Distraction		Construction site noise condition continuously distracted by sound stimulation	Sound conditions
Perceived Disturbance			
Additional Information*	EEG	EEG and subjective self-evaluation of attentional levels after each condition, EEG epochs categorised into "focused" (correct response, no noise distractor) and "distracted" (incorrect response, noise distractor present)	ECG measured during surgical procedure, conversations recorded

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[47] Leist et al. (2022a)	[50] Lim et al. (2021)	[52] Love et al. (2021)
Sample	Exp.1) 36 university students (19 female, 24.9 ± 3.9 years old, range 19-31 years), 37 second-graders (9 female, 7.4 ± 0.25 years old, range 6.25-8.2 years), 19 third-graders (12 female, 8.75 ± 0.33 years old, range 8.25-9.6 years)	90 subjects (42 male, 22.53 ± 3.75 years old, range 18-36 years), one British group and one Singaporean group	51 subjects (22 male, mean 23.1 years old, range 18-39 years)
Result	Speech perception was more impaired in the monaural condition compared to binaural condition. Listening comprehension and performance in serial recall task was not differentially affected by the presentation mode (monaural vs. binaural). There was a significant age effect, as children were more affected by the noise condition in general compared to adults. Disturbance ratings were not associated to actual performance	Background sounds had no significant effect on either the British or the Singaporean performance. There was also no main effect of extraversion, both extraverts and introverts did not differ in performance. Extraversion was a significant predictor of performance across groups on the mental arithmetic task (silence condition); in the British group on Raven's test (silence condition), and in the Singaporean group on mental arithmetic task (music condition)	Interaction effect: performance in n-back task drops when noise sensitivity level increases; no main effect of noise condition on performance, even though the noise conditions were rated as more effortful, frustrating, and burdensome. Main effect of task difficulty is also reflected in physiological measures. An effect of noise could be determined for heart period measure, where lower heart rate was observed during noise conditions compared to silence
Sound Quality	Three noise conditions: classroom background sounds (e.g., furniture, footsteps, paper rustling), multi-talker speech (non-intelligible, i.e., Hindi; child talking, four speech streams) either presented monaurally (i.e., no spatial separation, presentation from straight ahead of listener) or binaurally (i.e., sounds and speaker sources spread across room, switching locations randomly), compared against silence	Noise condition: office noise; music condition: english pop songs; silence condition	Three sound conditions: silence, C1 & C2; sound conditions: operating heating, ventilation, air conditioning, and refrigeration (HVAC&R) equipment
Level	speech signals LA,eq = 60 dB; classroom noises LA,eq = 63 dB	Noise and music condition: constant level between 60 and 70 dB	C1 = Loudness: 28.1, dBA: 71, Roughness: 5.44, Tonality: 0.17, Fluctuation strength: 0.012, Aures* sharpness: 1.54, Average annoyance rating: 4.81; C2 = Loudness: 27.1, dBA: 70.9, Roughness: 2.51, Tonality: 0.39, Fluctuation strength: 0.008, Aures* sharpness: 3.24, Average annoyance rating: 6.80
Workplace	classroom simulated		OPO simulated
Performance	Exp.1) Speech perception using word-to-picture matching task measured, and Listening comprehension using instructions for pen-and-paper test assessed; Exp. 2) serial recall of monosyllabic words presented pictorially	Abstract reasoning: Advanced Raven's Progressive Matrices Set II; Verbal Reasoning Test; Mental Arithmetic Test	d' on N-back task
Task Load			0-back, 1-back, 2-back, and 3-back task; NASA TLX to determine subjective workload and annoyance
Annoyance			NASA TLX dimensions of effort and frustration
Distraction			Background sounds
Perceived Disturbance	Assessed using smiley scale from 0-4		
Additional Information*	Age, presentation mode (binaural vs. monaural)	Personality (Big Five Inventory-2 (BFI-2) questionnaire) and IQ (Wonderlic Personnel Test (WPT)) measured, influence of extraversion as potential moderator, two national groups compared	Measured physiological indicator of stress (Electrodermal activity (EDA), heart period, heart rate variability (HRV), capillary dilation (BVPA), facial electromyography (EMG)); personality traits (Big Five inventory); and noise sensitivity (NoiSeQ)

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[58] Masullo et al. (2021a)	[59] Masullo et al. (2021b)	[60] Meinhardt-Injac et al. (2022)
Sample	24 university students (12 female, 30 ± 6.1 years old, range 24-48 years)	18 students (7 female, 29 ± 4.4 years old, range 22-38)	182 participants; Group 1) 57 younger children (35 female, 9.2 ± 0.6 years old); Group 2) 73 older children (44 female, 11.3 ± 1.0 years old); Group 3) 52 young adults (39 female, 23.6 ± 3.2 years old)
Result	Interaction effect of gender for verbal fluency: under low and medium variability, females showed higher verbal fluency than men, but decreased performance in Hv. Contrary, males showed higher performance on visuospatial working memory test unaffected by sound condition	Low and modulated noise conditions negatively impacted visuo-spatial working memory and executive functions in the Backward counting task, as well as semantic recall abilities	Cognitive performance with classroom noise stimulation only decreased in the serial recall task, but not the paired-associate recall task in all three age groups. There was only an association between the inhibition efficiency as measured by Stroop task and the ISE in the young adults group, but not in the sample as a whole.
Sound Quality	Four sound conditions: quiet office (Ctrl), sound conditions: recordings from different dwellings with distinguishable urban noise pattern = low variability (Lv), medium variability (Mv), high variability (Hv), variability: relates to stability of traffic flow and number of noise sources	Four sound conditions: 1) low-frequency noise (LF), 2) high-frequency noise (HF), 3) modulated noise (MOD), 4) control (CTRL)	Two sound conditions presented during encoding of recall tasks: silence vs. classroom noise (recorded during group work with soft but audible conversations)
Level	Ctrl = 41 dBA, Lv = 56.2 dBA, Mv = 52.1 dBA, Hv = 51.2 dBA	LF, HF, MOD: 80 ± 1 dBA; CTRL: 51 dBA	ca. 55-60 dBA
Workplace	Background noise in office with open windows simulated		
Performance	Verbal fluency by phonemic categories measure, Rey auditory verbal recognition memory test, Backward counting	Rey Test, the Verbal Fluency Test, and the Backward Counting Test, while operating an overhead crane in VR and performing a manoeuvring task	Serial recall task and paired-associate task
Task Load		Dual load paradigm with VR-task and cognitive task	
Annoyance			
Distraction			
Perceived Disturbance	Subjective rating of concentration and distraction on 10-point Likert scale		
Additional Information*		Go/No Go to examine inhibitory control and sensitive interference	Inhibition efficiency and interference measured using Stroop task

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[62] Monazzam Esmaielpour et al. (2021)	[64] Mueller et al. (2022)	[66] Niazmand-Aghdam et al. (2021)
Sample	325 male automotive industry workers (36.46 ± 7.18 years old, work experience 13.26 ± 5.15 years)	Exp.1) 21 participants (11 female, 28.52 ± 12.1 years old); Exp.2) 57 participants (31 female, 27.53 ± 7.79 years old)	24 male subjects (22.74 ± 2.99 years old, range 20-30 years)
Result	Both work ability and mental disorder indexes are significantly decreasingly and increasingly associated with noise exposure, respectively. Other demographics like age, work experience, individual and averaged daily exposure to noise were found to be influential as well	Compared to speech conditions, performance on the serial recall task in silence was always better, suggesting an Irrelevant-Speech-Effect. Active-Noise-Cancelling headphones did not have an influence on the cognitive performance in either condition (ANCoff nor ANCon) compared to noHP. Significant improvements were found in the subjective ratings of the participants, especially for annoyance and concentration ratings. Furthermore, in the ANCon condition, participants felt more private and assessed their acoustic environment more positively	Increase in noise levels negatively affected performance in the auditory attention task
Sound Quality	Noise exposure recorded during workers' shift according to ISO-9612 standard	Exp.1) Four sound conditions: silence vs. speech without headphones (noHP) vs. speech with ANC headphones switched off (ANCoff, only Exp.1)) vs. speech with ANC headphones switched on (ANCon)	Three noise conditions: background noise, traffic noise: guideline threshold, and traffic noise: exceeding guideline
Level	Average noise exposure over limit : pressing unit = 90.5 ± 8.2 dBA; cutting unit = 89.3 ± 7.7 dBA; screw making unit = 88.5 ± 4.5 dBA; average noise exposure within permitted limit : administrative unit 54.3 ± 1.3 dBA; moulding unit = 84 ± 3.2 dBA; die casting unit = 82.5 ± 1.5 dBA; merger and acquisitions unit = 78.8 ± 1.6 dBA	Silence = background sounds of 35 dBA, speech conditions = 59 dBA at 1 m distance, anechoic recordings of the Oldenburger Satztest, Exp. 1) only male speaker (target) and three female speakers from different locations, Exp.2) only one female speaker	Background noise = 27 dBA, traffic noise: guideline threshold = 55 dBA, traffic noise: exceeding guideline = 85 dBA
Workplace	Automotive industrial work	Simulated open plan office (OPO)	Simulated driving occupation
Performance	No cognitive performance measures assessed	Serial recall task: digit span	Go-No-Go- Attentional task: IVA+Plus (Integrated Visual and Auditory) test
Task Load	Workers' work ability index measured (Shortened form of work ability index) and mental disorders index (Kessler Psychological Distress Scale questionnaire)	Subjective rating of perceived performance and ability to concentrate on five-point Likert scale	
Annoyance		Subjective rating of perceived disturbance/annoyance on five-point Likert scale	
Distraction		Subjective rating of perceived loudness on five-point Likert scale	
Perceived Disturbance		Subjective rating of perceived long-term disturbance on five-point Likert scale (only Exp.1)	
Additional Information*			Effect of vibration tested additionally

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[73] Pieper et al. (2021)	[76] Radun et al. (2022)	[77] Rahmani et al. (2021)
Sample	29 healthy adults (14 females, mean age: 34.62 years, SD=12.62)	59 participants (39 female, mean age 24.8 years, range 20-48 years)	103 male bus drivers (42.48 ± 6.73 years old)
Result	Mental load and subjective stress was higher in the noise condition compared to no noise and noise-cancelling condition. ERPs could differentiate between no noise and the other two conditions	Impulsive sounds lead to higher annoyance and workload ratings, increased fatigue, and higher physiological stress responses compared to the quiet condition, as well as significantly decreased cognitive performance during high mental workload (3-back task). Compared to steady-state sounds, impulsive sounds score worse in the psychological ratings, indicating a more stressful experience even though SPL levels were constant. This effect was not replicated in performance or physiological measures.	Accuracy of Stroop test and reaction time of answers decreased and increased respectively after driving. Noise and vibration significantly negatively affect accuracy and increase reaction time within the Stroop test
Sound Quality	Auditory stimulation presented via headphones, sound condition manipulation (no noise vs. noise environment vs. noise environment + noise-cancelling) presented via loudspeakers	Three sound conditions: quiet sound (pseudorandom pink noise) vs. steady-state sound (pseudorandom pink noise) vs. impulsive sound (outdoor recording of construction site, pile driving)	Bus drivers exposed to the natural sound environment of their bus route during driving (traffic noise, urban noises, passenger noises)
Level	Task instructions: 70dB, noise via loudspeakers: 76 dB SPL	Quiet sound = 35 dB LAeq; steady-state and impulsive sound = 65 dB LAeq	Average noise exposure: 79.50 ± 3.51 dB
Workplace	OPO		Bus drivers during work
Performance	Solve spoken arithmetic tasks, task instructions presented auditorily	N-back task; digit span task: Auditory serial recall (ASR) and Visual serial recall (VSR)	Stroop test before and after driving
Task Load	NASA Task Load Index (NASA-TLX) for measuring subjective workload	N-back task = 0, 1, 2, 3-back	
Annoyance	Self-Assessment Manikin (SAM) for measuring affective state of participant	Annoyance rated on scale 0-10	
Distraction			
Perceived Disturbance	Subjective rating scale (SRS) of experienced effort	Perceived workload rated on scale 0-10; perceived fatigue rated using SOFI	
Additional Information*	Speech Intelligibility: Noise environment = speech (spoken numbers and news broadcast snippets) and environmental sounds (noise recorded from cars, public dwellings); EEG measured	Groups were balanced based on Weinstein's 21-item noise sensitivity scale, physiological measures assessed (Blood pressure, HRV: LF/HF ratio, Stress hormone concentration: Cortisol, Noradrenaline)	Job Stress Levels measured (Philip L. Rice occupational stress questionnaire), noise exposure of drivers quantified, vibration exposure of drivers quantified

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[85] Sander et al. (2021)	[86] Schäffer et al. (2022)	[88] Sheikhmozafari et al. (2021)	[90] Shkembi et al. (2022)
Sample	40 healthy subjects (6 male, 22.65 ± 6.15 years old, range 17-44 years)	Exp 1) 24 subjects (11 females, median 28.5, range 19-63 years); Exp 2) 25 subjects (12 females, median 33, range 26-61 years)	66 OPO employees (22 female, 33 ± 6.75 years old)	Adult miners from Illinois, Michigan and Ohio
Result	Even though noise did not affect cognitive performance, high noise induced a higher amount of stress and reduced psychological well-being as assessed by subjective self-reports, physiological indicators of stress, and facial expressions of emotion	Annoyance ratings decrease when there are more quiet periods and when those periods are more regular. The macro-temporal pattern of the noise stimulation did not affect cognitive performance, only QTD showed an association with reaction time	Employees in open-plan offices (OPO) showed increased sensitivity to noise, especially audible conversations and telephone ringing were deemed as very annoying. In general, satisfaction with work environment was moderate, as the workplace noise was rated as high and annoying	High mental workload was associated with increased average and peak noise levels (noise exposure greater than >135dB)
Sound Quality	Two noise conditions: simulated open plan office (OPO) background high noise (people speaking, walking, printing papers, ringing telephones, and keyboard typing noises) vs. simulated private office low noise (air-conditioning and computer fan noise)	Two conditions: traffic noise and low background noise (silent control condition)		Noise exposure recorded during workers' shift
Level	Low noise condition = 36.3 dB; high noise condition = 59.1 dB	Exp.1) background noise: 30 dBA, traffic noise: 42-45 dBA; macro-structural pattern of sound condition varied = Relative Quiet Time (RQT, four levels: 0.0%, 44.3%, 62.9%, 81.5%), Intermittency Ratio (IR), Centre of Mass Time (CMT), Quiet Time Distribution (QTD. two levels: regular vs irregular); Exp.2) constant dBA, RQT, and three levels of QTD: regular quiet periods, a combination of short quiet periods and six 1-min quiet periods, or two 3-min quiet periods		Average noise exposure = 85.1 ± 5.9 dBA, kurtosis of noise = 2.7 ± 1.5 dBA
Workplace	Simulated OPO	Simulated office environment with open windows	OPO	Mining site
Performance	Proof-reading task, detection of typographical errors	Visually presented Stroop Task	No objective performance measures taken	
Task Load				Mental workload was assessed with NASA-TLX
Annoyance		Subjective annoyance rated after each trial using the ICBEN noise annoyance question	Assessment of noise effects on employee comfort using subjective questionnaire	
Distraction		Road traffic noise		
Perceived Disturbance				
Additional Information*	Objective physiological measures of stress investigated (heart rate measures, electrodermal activity [EDA]), measures of affect investigated (PANAS, facial expression of emotion)			Hearing Protection device (HPD) use measured

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Author	[95] Sugimoto et al. (2022)	[98] Tseng et al. (2022)	[111] Zhang et al. (2022)
Sample	28 participants (3 female, age range 18-32 years)	20 circulating nurses (CNs) and 16 nurse anaesthetists (NAs)	22 university students (10 participants in plants present group, 12 in plants absent group)
Result	For the subjective ratings there was a main effect of task load, where the fast condition was rated as more difficult, effortful, enjoyable, and immersive compared to the slow condition. There was no effect of interval length or variability of the task-irrelevant auditory probes. This effect on working load was also found in the ERP signal (decreased amplitude in N1 & P2). To be able to distinguish between high and low working load, decreasing the interval length between stimuli does not effectively decrease the total time needed to obtain reliable ERPs	Main effect of sound condition: workload and state anxiety highest in noisy environment and lowest with Mozart's music. These scores were also higher in the higher sound level compared to lower sound level	Participants working in the presence of plants show a consistent trend of decreased accuracy rates and decreased pupillometry responsivity (higher dilation and lower saccade frequency), but there were no significant effects. Mental workload ratings increased with increasing traffic noise levels (TNL), and were higher in the plants-present group. There was a significant interaction between plants and TNLs on sound disturbance, acoustic satisfaction, and layout satisfaction, even though this effect can mainly be attributed to changes in TNL
Sound Quality	Four sound conditions: interval length (long vs. short) vs. interval variabilities (variable vs. fixed)	Operating noise without music; Chinese pop songs; radio program broadcasting; or Mozart's music	Five sound conditions: quiet condition vs. traffic noise at 4 dBA levels
Level	12 pure tones of 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, or 1600 Hz, presented as random sequence with equal probabilities at approximately 75 dB/SPL binaurally	Low: 55 dB-60 dB; high: 65 dB-70 dB	Background noise level = 35dBA; traffic noise conditions (TNL) = 45, 50, 55, and 60 dBA
Workplace		Operating room	Home Office
Performance	Driving simulation game	Situation Awareness Global Assessment Technique (SAGAT)	English Reading Comprehension Task (ERCT), and 5-minute micro break between questionnaire assessment
Task Load	Slow (car could only drive 30km/h) vs. fast (car could drive 200km/h), subjective rating of degree of task demand and effort after each condition	Assessed using Subjective Workload Assessment Technique (SWAT)	Assessed using NASA-TLX
Annoyance	Subjective rating of degree of interest and immersion in task after each condition		
Distraction	Sound conditions		
Perceived Disturbance			Participants' perceived quality of the acoustic (sound disturbance, acoustic satisfaction) and non-acoustic environment (layout-, thermal-, lighting-, and air quality satisfaction), and the short-time break (mental and visual fatigue-, anxiety-, and unfriendly- recovery) assessed
Additional Information*	25-channel EEG recorded	State-Trait Anxiety Inventory-State (STAI-S) assessed	Two groups: plants present = two plants were next to participants while they performed the test; plants absent: no plants; eye tracking assessed

*Speech Intelligibility, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator

Table 2: Overview of Basic Research Studies

Author	[1] Abbasi et al. (2022)	[2] Alali-Morlevy et al. (2022)	[3] Alikadic et al. (2022)
Sample	32 healthy subjects (16 males, males: 23.81 ± 3.8 years old, females: 22.62 ± 1.02 years old, range 20-30 years)	Exp. 1) 36 students (18 silent group 29.56 ± 4.9 years old, range 22-37; 18 sound group 27.22 ± 3.7 years old, range 21-35) Exp. 2) 42 students (21 silent group 23.9 ± 2.56 years old, range 20-29; 21 alerting tone group 26.18 ± 3.94 years old, range 21-35)	130 participants (87 female, 22.90 ± 3.9 years old)
Result	Main effect of gender: females rated higher in annoyance and fatigue across sound conditions; interaction effect of noise exposure on cognitive performance per gender: in low workload, female performance was higher compared to male, in high workload, male performance (accuracy) was improved. A nonsignificant interaction effect was shown for the physiological stress indicator: with increasing levels of noise and workload, the mean LF/HF ratio increased more for females compared to males	Sound functions as a moderator of the correlation between MW and ADHD symptoms (=sound reduces the association between MW and ADHD symptoms).	The disruption caused by changing-state sequences compared to steady-state sequences is independent of intensity (45dB(A) compared to 75dB(A)). There was a main effect of intensity (sequences presented at 75dB[A] were more disruptive compared to presentation at 45dB[A]), indicating a more pronounced role of intensity than previously assumed. There was no intensity effect on auditory deviants, as they were equally disruptive for both intensity levels
Sound Quality	Four noise conditions, within-subject design	Exp. 1) Sound group completed the task while listening to trance music Exp. 2) alerting tone group performed the task while hearing a 30ms 1975 Hz alerting tone with 10s between the tones	Six sound conditions: Low-intensity steady-state; High-intensity steady-state, Low-intensity changing-state, High-intensity changing-state, Low-intensity auditory deviant, High-intensity auditory deviant
Speech Intelligibility			
Level	55 dB(A)(background noise level), 65 dB(A), 70 dB(A), 75 dB(A)	Exp. 2) Alerting tone = 1975 Hz	Low intensity stimuli presented at 45dB(A); high intensity stimuli presented at 75dB(A)
Performance	N-back test with concurrent noise stimulation	Exp. 1 + 2: Modification of CPT task	Visually presented digit serial recall task
Task Load	Low workload (n = 1), medium workload (n = 2), high workload (n = 3)	Dundee Stress Test measured	
Distraction		Questionnaire regarding tendency for mind wandering in everyday life	One-syllable nouns as distractor
Perceived Disturbance			
Additional Information*	Annoyance: Subjectively rated after each session/sound condition using Visual Analog Rating Scales (VAS); Noise-induced fatigue measured with VAS, and Heart Rate Variability (HRV) measured (LF/HF ratio)	ADHD symptoms assessed using DSM-5	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[4] Aloysius et al. (2023)	[8] Anandan et al. (2021)	[9] Ascone et al. (2021)
Sample	6 participants (3 female, 23.5 ± 0.84 years old)	5 adults with normal hearing (4 females, age: 20-38)	23 subjects (10 male, 27.35 ± 6.44 years old) and 15 controls (5 male, 25.60 ± 4.76 years old)
Result	BB stimulation increased reaction times in the n-back task, non-significantly modulated by task load. Also, it increased accuracy in the post-BB exposure task. GWN increased cognitive resource recruitment in areas indicated with attentional processing, while AWN increased activation in working-memory related areas, suggesting successful entrainment	Presence of background noise is not crucial for attentional filter generation, which opposes the anti-masking hypothesis. Auditory attention is suggested to be driven by top-down cortical control which is independent of noise	Infrasound did not have an effect on human behaviour, e.g. sleep, cognition parameters. It is suggested to have an adverse effect on the cortical structure of cerebellar and temporal areas, potentially indicating a decline in higher auditory processing
Sound Quality	Three sound conditions: binaural beats (BB) stimulation with either 1) alpha embedded in white noise (AWN) vs. 2) gamma embedded in white noise (GWN) vs. 3) pink noise (control, no BB, PN)	Quiet condition vs. background noise condition (white noise, 0.2-18Hz)	Infrasound sources omitted a steady SPL for eight hours during participants' sleep time, placed next to them in their bedroom vs. sham device
Speech Intelligibility			
Level	SPL level for all stimuli = 75dB, alpha frequency = 9.55 Hz; 230 Hz and 220.45 Hz; gamma frequency = 40 Hz; 440 Hz and 480 Hz	dB-level of target based on individual threshold detection; exp. 1 = one target sound (1kHz), four probes (0.8, 0.92, 1.08, 1.2 kHz); exp.2 = 100% target sound (0.8, 1, or 1.2 kHz); exp.3= 20% target sound randomly selected from 0.8, 0.92, 1, 1.08, or 1.2 kHz; noise = 65 dB SPL	80-90 dB SPL, 6 Hz
Performance	Visual n-back task before and after auditory stimulation	Signal detection task of masked target stimuli, with noise or quiet condition as within subject design, with cued/uncued trials	Computer-based Tests of Attentional Performance (TAP) for cognitive assessment, furthermore spatial n-back task during MRI session
Task Load	Low: 0-back task vs. medium: 1-back task vs. high: 3-back task		
Distraction			
Perceived Disturbance			
Additional Information*	fMRI measured		Subjective self-reports, Brief Symptom Inventory (BSI), Perceived Stress Scale (PSS), Epworth Sleepiness Scale (ESS), NOISEQ, SISUS-Q, Pittsburgh Sleep Quality Inventory (PSQI), five-factor personality inventory (NEO-FFI-3)

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[11] Bell et al. (2022)	[12] Blain et al. (2022)	[13] Blomberg et al. (2021)
Sample	Exp 1) 189 participants (143 females, 23 ± 4 years old, range 17-38 years); Exp 2) 213 participants (166 females, 23 ± 4 years old, range 17-42 years)	Exp 1: 16 non-musicians (4 males, range 20-33 years); Exp 2: 16 musicians (4 males, range 18-34 years); Exp 3: 16 non-musicians (5 males, range 19-28 years)	17 adult ADHD patients (11 female, 27 ± 7 years old; 6 male, 29 ± 7 years old); 17 neurotypical control (13 female, 25 ± 4.9 years old; 4 male, 26 ± 6.2 years old)
Result	The increased disruptive effect of changing-state sequences compared to steady-state sequences on serial recall was found and replicated in Exp. 2). This effect was also reflected in the metacognitive ratings, even though the susceptibility to distraction of individual participants was not predicted by subjective metacognition-ratings	Interaction effect: both groups (musicians and non-musicians) are more affected by the difficult distractor compared to the easy distractor, as well as by the difficult memory task compared to the easy memory task, but non-musicians are more affected by the distractor in general compared to musicians. Musicians showed a greater difference between the distractor-levels in the difficult memory task compared to the easy memory task. Using a version of the paradigm without the distractor melody evidence supports the cognitive load theory	Under high WM load (2-back task), aADHD were more affected by the task-irrelevant distractor sounds compared to controls. Increased functional connectivity between auditory and saliency networks was detected for aADHD in the auditory detection task, suggesting increased recruitment of those networks, compared to controls, to reduce negative effects of the auditory distractor
Sound Quality	3 sound conditions: steady-state (same monosyllabic word) vs. auditory-deviant (same monosyllabic word beside the 6th word) vs. changing-state sequences (words presented random)	Four-note-long melodies spanning two octaves between 110Hz and 440Hz	ADT: standard tone = 500 Hz, deviant tone = 1000Hz
Speech Intelligibility			
Level	65 dB(A) Leq		Background sound of scanner attenuated using active noise cancelling headphones to ~58 dB SPL, auditory stimuli presented at ~75 dB SPL
Performance	Serial recall using digit span task	Memory task: S1 is played together with distractor melody, after retention delay period S2 is presented (S2 = S1 with one note different or same melody). Participants indicate whether S1 is different/same compared to S2. Perception task: change detection of last note, can be different or identical to previous note	Auditory detection task with oddball tones with distractor noise and visual stimulation (of n-back task); visual n-back task with same auditory stream as distractor
Task Load		WM: low memory-task difficulty (low MEMdiff) = replaced note is six or seven semi-notes apart; high memory-task difficulty (high MEMdiff) = replaced note is one or two semitones apart. Perception task: low perception-task difficulty (low PERdiff) last two tones are three or four semitones apart	N-back task with three conditions: 0-, 1-, and 2-back WM condition
Distraction	Task-irrelevant speech	S1 = melody to encode, DIS = distracting melody, to be ignored, played interleaved in contralateral ear. Level of distraction manipulated by frequency range of distracting melody, easy = notes are separated by six or seven semitones from S1; difficult = distractor melody same frequency range as S1. In Exp. distractor can be absent	Auditory task: visual stream; visual task: auditory stream
Perceived Disturbance			
Additional Information*	Metacognitive beliefs assessed in Exp 1) (verbal description of sound condition, only metacognition assessed) and Exp 2) (presentation of sound stimuli, assessment before and after the digit span task)		fMRI measured during task performance (functional connectivity and Region-of-Interest (ROI) analyses)

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[14] Daly et al. (2021)	[15] Dámian-Chávez et al. (2021)	[16] De Winne et al. (2022)
Sample	22 university students (11 female, age range: 18-22 years)	16 students (7 female, age range 19-25)	41 participants (20 female, 23.71 ± 2.69 years old)
Result	Detection performance increased in all conditions when a predictable distractor sound appeared. On the contrary, irregular distractor sounds negatively impacted detection time, suggesting a suppression mechanism of frequently-occurring distracting sounds which is involved in selective attention	Student teams performing in quiet condition showed better performance compared to library noise condition. Physiological measures indicated increased arousal and/or stress responses in the noisy condition	Conditions with auditory support increased performance in the visual digit span task, but no effect of rhythm (rhythmic vs. non-rhythmic sounds) was found. Participants who perceived the sounds as supporting showed improved performance in the auditory support conditions, whereas participants who perceived it as disturbing showed no significant difference between conditions. Auditory dominant participants show better performance in all four conditions compared to visual dominant participants
Sound Quality	Six streams of spoken digits (always only odd or even numbers, 1-4,6-9), three different male and three different female speaker. Distractor stimuli: environmental sounds (bird tweet, guinea pig squeak)	Two sound conditions: quiet vs. library noise	Four audio-visual conditions: visual targets presented non-rhythmically (C_1-NoSupp); visual targets presented rhythmically (C_2-VisRhythmSupp); visual targets presented non-rhythmically, synchronised non-rhythmic audio support (C_3-AudSupp); visual targets presented rhythmically, synchronised rhythmic audio support (C_4-AVRhythmSupp)
Speech Intelligibility			
Level	68 dB	Library noise condition = Leq of 78 dBA	70 dB SPL
Performance	Detection of target voice: detect speaker with certain gender and determine the digit sequence (odd vs. even)	Teamwork performance measured using assembly of puzzle	Pre-test: audiovisual dominance test = classification of two objects with either only visual, only auditory, or visual and auditory features to determine if participants are rather auditory dominant or visual dominant; Performance test = modified digit span task, digit target sequence presented interleaved with either blank or distractor digit presentation
Task Load			After experimental runs, participants were asked about their perception of the difficulty of the task
Distraction	Three distractor conditions: no distractor present, four talkers (none condition), distractor occurred with 70% probability (high condition), distractor occurred with 30% probability (low condition)		
Perceived Disturbance			After experimental runs, participants were asked about their perception of the sound and rhythm
Additional Information*		4-channel EEG (Muse Headband), ECG, and Blink rate measured	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[17] Di Battista et al. (2022)	[18] ElShafei et al. (2022)	[19] Elliott et al. (2022)	[20] Engelbregt et al. (2021)
Sample	40 participants (9 male, 20 ± 2 years old, range 18-26)	28 healthy subjects (younger group: 5 female, median 25.5 years old, range 20-29 years; older group: 5 female, median 66.5 years old, range 60-75 years)	128 healthy subjects (Psychology in-person: n = 46; Psychology online: n = 42; Online panel: n = 40)	25 university students (11 female, 21.8 ± 2.5 years old, range 18-28 years)
Result	There was no effect of ultrasound exposure on either the reaction time or accuracy of participants' performance	Older adults are more distracted by the later distractor compared to young adults. There is no difference between groups for an arousal effect of distractor (early distractor) or cue benefit. Older adults show an enhanced processing of task-irrelevant information, reduced inhibitory control, and need more time to reorient themselves towards the task after an auditory distraction compared to the younger group	ISE successfully replicated in all three groups, as well as key signatures of auditory distraction effects with similar effect sizes. Suggests that auditory distraction studies can be performed online	Binaural beat stimulation improved participants performance significantly compared to pink noise, which in turn significantly improved performance compared to monaural stimulation. This behavioural attention effect could not be replicated in the EEG recordings, questioning the occurrence of neural entrainment
Sound Quality	Two sound conditions: no noise vs. ultrasound exposure	Target sounds: monaural pure tones (512 and 575 Hz); distractor sounds: 40 different ringing sounds	Three sound conditions: (changing-state sounds, steady-state sounds and silence	Three sound conditions: Pink noise (PN), monaural beats stimulation (MB), binaural beats stimulation (BB)
Speech Intelligibility				
Level	Ultrasound = 40 kHz tone, 120 dB SPL re 20 µPa	Level individually determined (Bekesy tracking method)		
Performance	Go-NoGo task (GNG) and continuous performance test (CPT)	Performed competitive attention task (CAT): visual cue (arrow left or right, [informative] or both sides simultaneously [uninformative]) for target sound location. 25% of trials the distractor sound is played between cue and target presentation. Task: categorise low- and high-pitched target sounds	Irrelevant Sounds task: recall of digit-sequence under background sound conditions	Flanker task for attention measurement
Task Load				Three difficulty levels of Flanker task
Distraction		Distractor sound (e.g., phone ringing, doorbell,..) played either during early delay phase (DIS1) or late delay phase (DIS2)	Background speech (repetition of different or same spoken letters)	
Perceived Disturbance				
Additional Information*		MEG and EEG simultaneously collected	Comparison of three groups: two groups online, one on-site, measured in the lab	19-channel EEG recording of frontal areas

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[23] Gao et al. (2021)	[24] Georgi et al. (2022)	[25] Gheewalla et al. (2020)
Sample	Exp.1) 20 university students (6 male, 23.5 ± 2.4 years old); Exp.2) 32 university students (6 male, 21.2 ± 1.9 years old); Exp.2) 30 university students (7 male, 23.7 ± 2.4 years old)	Group 1, verbal task - 70 participants (44 female, median age 21 years, range 17-40 years); Group 2, visual-spatial task - 70 participants (44 female, median age 21 years, range 18-40 years)	55 participants (15 male, 21.75 ± 4.28 years old, range 18-38)
Result	The Pip-and-Pop effect, which denotes the facilitation of recognition of visual targets via synchronised auditory stimulation, was not replicated in a static visual task, but was replicated in a dynamic task. The Pip-and-Pop effect was decreased in the two-sound condition compared to the one-sound condition, suggesting it is likely to stem from the attentional effect of an oddball paradigm	Cognitive performance in the verbal task was more negatively affected during unaltered speech stimulation in comparison to sinewave speech (SWS), and more affected in the changing-state condition compared to steady-state, presenting as two independent effects. Cognitive performance in the visuospatial task showed a contrary behaviour for speech: SWS was more disruptive than unaltered speech, but the disruption caused by changing-state followed the same pattern as in the verbal task. There was no moderating association between working memory capacity and the negative impact of the ISE in either task	Significant main effect of sound condition, where reading comprehension speed was more affected (i.e., slower) during white noise and sirens background presentation compared to silence in a linear fashion. There was no interaction between distraction and extraversion
Sound Quality	Exp. 1+2) 50% of trials: auditory stimuli presented simultaneously to a visual colour change (No-sound condition vs. With-sound condition); Exp. 3) additionally Two-sound condition: two colour changes associated with a tone, respectively	Silence vs. four irrelevant sound conditions (changing state + sinewave speech (SWS); steady-state + SWS; changing-state + unaltered speech; steady-state + unaltered speech); speech stimulus: sequence of syllables (same or random set of 31 syllables); sinewave speech: syllable sequence processed by sinewave synthesis	Three sound conditions: quiet vs. white noise vs. police sirens
Speech Intelligibility			
Level	500-Hz tone	Silence = LAeq 28 dB(A); changing-state speech = LAeq 57 dB(A); steady-state speech = LAeq 60 dB(A); changing-state SWS = LAeq 58 dB(A); steady-state SWS = LAeq 62 dB(A)	Both noise conditions = 85dB
Performance	Visual search task (Exp.1=static, Exp.2 +Exp.3=dynamic)		Reading comprehension task
Task Load	Three set size conditions: six, ten, or twenty		
Distraction	Visual target presented with distractors	Sound conditions	Sound conditions
Perceived Disturbance			
Additional Information*	Pupillometry measured	OSPAN task measured as quantification of working memory capacity as pretest	Extraversion Questionnaire measured

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[27] Guitard et al. (2021)	[28] Han et al. (2021)	[29] Hao et al. (2021)
Sample	Exp 1) 32 university students (28 females, 18.78 ± 1.39 years old, range 17-22 years); Exp 2) 32 university students (27 females, 19.91 ± 1.40 years old, range 18-24 years)	44 healthy adults (18-25 years old, recruited separately in two groups)	126 participants (80 female, 23.48 ± 5.25 years old, range 18-45 years)
Result	Regardless of response modality (manual vs. oral) and foreknowledge about recall condition (forward vs. backward), the Irrelevant speech effect (ISE) was detected for forward recall. In the backward recall condition, the influence of background speech was diminished if the response was given orally compared to manual responses. With foreknowledge of recall condition, ISE was decreased when responses were given manually and absent during oral responses	In noise conditions (background speech and white noise) visual WM performance is enhanced. An increase in arousal for noise conditions was measured with physiological recordings. No interaction effect of cue type was found	Reading comprehension performance is improved in high perceptual load (difficult font) and for participants with high WM capacity. There is no interaction effect of perceptual load or WM capacity on background sound condition, contradicting the shield effect of perceptual disfluency against auditory distraction
Sound Quality	Two sound conditions: control vs. irrelevant speech; speech stimulus: spoken digit sequence (1-9) in random order, spoken by male speaker	Background quiet condition (BQ) vs. background white noise (BW) condition vs. background speech (BS) condition	Three noise conditions: content-related speech (another story), meaningless speech (story backwards), and no noise
Speech Intelligibility			
Level		Quiet condition: 37 dB; noise conditions: 55dB	Constant level (sound setting: 20) for all participants
Performance	Forward and backward serial recall (word sequences), response modality manipulated (typing response; manual vs. speaking the response; oral)	Visual WM task with or without cue	Reading comprehension for prose passages (multiple choice test after reading); WM capacity (no sound conditions) assessed using reading span and rotation span task
Task Load	Exp 1) participants informed about recall direction (forward vs. backward) after stimulus presentation immediately before recall, Exp. 2) recall direction was known before stimulus presentation (same recall condition during one block)		Perceptual Disfluency: hard-to-read font vs. easy-to-read font
Distraction	Sound conditions		Noise conditions
Perceived Disturbance			Subjective ratings on 7-point scale about perceived difficulty of reading comprehension test
Additional Information*		Electrodermal activity measured	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[30] He et al. (2021)	[31] Huda et al. (2021)	[36] Kattner (2021)
Sample	34 participants (15 female, 22.0 ± 2.8 years old, range 18-29 years)	10 research lab assistants (5 female)	74 participants (24 male, 24.7 ± 7.5 years old, range 18-62 years)
Result	Performance decreased and pupil size increased with increased mental load of the visual task. Processing of task-irrelevant stimuli, but not attention towards them (P3a) was observed to follow a non-monotopic pattern under workload: Mismatch-negativity increased with increasing task load but decreased again under high workload. The auditory distractor had less adverse effect on attentive processing of high-reward compared with low-reward visual stimuli as indicated by reduced P3a	Main effect of sound condition on cognitive performance, better performance in the 45 dB condition observed. No effect of gender observed	Training in the dual n-back task improved Irrelevant Speech effect (ISE) scores in the inhibitory n-back group, but not in the standard n-back or control group, suggesting an enhanced resistance against auditory distractor transferred from inhibitory WM training. Conclusive evidence in favour of transfer effects in other task-unrelated cognitive domains was not found.
Sound Quality	Visual attention task with auditory oddball distraction	Two sound conditions: conversational sounds of two levels	Verbal serial recall task: interference by task-irrelevant background speech (Finnish speech, no semantic meaning) or white noise
Speech Intelligibility			
Level	Standard tone = 1,000 Hz; deviant tone = 1500 Hz; tone duration 50 ms; ~55 dB SPL; SOA 600 ms	45 dB and 85 dB	
Performance	Visual attentive rewarded tracking task: visual stimuli moving across screen, cued targets have to be attentively tracked and correctly detected (i.e. tracked) targets were monetarily rewarded (high vs low reward)	Stroop test	Transfer effect of n-back task investigated on five pre-post tests: working memory updating task; visual Simon task; verbal serial recall task with auditory distractor (background speech); task-switching trials, short form of Raven's Advanced Progressive Matrices.
Task Load	Either one, three, or five targets had to be tracked		Eight 90-min sessions of dual n-back test: visual task (squares) and auditory task (spoken letters), n adapted based on average performance in previous trials. Three groups: n-back group press button whenever target was same as n-back; inhibitory n-back group same paradigm, but press button whenever target was not the same as n-back and inhibit response if it is, control group =no n-back training
Distraction	Standard tone in oddball = 80% probability, deviant tone in oddball = 20% probability	Task performance measured under two sound conditions	Verbal serial recall task: background noise interference
Perceived Disturbance			
Additional Information*	Pupillometry and EEG measured	EEG recorded using "Muse Headband", gamma band during Stroop decision making investigated	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[37] Kattner et al. (2022a)	[38] Kattner et al. (2022b)	[39] Kattner et al. (2022c)
Sample	Exp.1) 36 participants (14 male, 24.7 ± 6.0 years old, range 19-45 years); Exp.2) 53 participants (12 male, 22.4 ± 4.0 years old, range 18-40 years); Exp.3) 66 participants online (15 male, 21.3 ± 4.7 years old, range 18-54 years); Exp.4) 42 participants online (10 male, 22.1 ± 5.6 years old, range 19-56 years)	Exp. 1) 31 participants (22 female, 22.1 ± 5.1 years old, range 18-35); Exp. 2) 101 participants (72 female, 28.8 ± 11.1 years old, range 18-70); Exp. 3) 72 participants (24 female, 2 non-binary, 29.9 ± 12.1 years old, range 18-72)	96 participants (57 female, 38 male, 1 other)
Result	There was no effect of visual task load on auditory distraction. Changing-state sound and auditory deviants negatively affected recall performance and confidence judgments compared to steady-state condition. Distractor effects might not be differentially related to perceptual load and recruitment of attentional resources	Changing-state trials disrupted serial recall in all three experiments, but not seriation-independent arithmetic task performance, suggesting interference with processing of serial order. Deviant speech stimuli did not interfere in serial recall or simple arithmetic tasks, but affected performance in a more demanding arithmetic task which did not rely on serial rehearsal, suggesting attentional distraction in highly demanding cognitive tasks	Foreknowledge of an impending distractor reduced its disruption of visual-verbal serial recall but only if it was at least partially intelligible (50%)
Sound Quality	Recordings of letters, three conditions: steady-state = always same stimuli for trial, changing-state = all 13 stimuli randomly presented, deviant = oddball with 1 stimulus as deviant	Auditory oddball steady-state or changing-state sequence: speech stream of male speaker with consonant names, either same consonant (steady-state) or randomly drawn consonants (changing-state); deviant present trials: 12th consonant replaced by consonant spoken by female speaker, Exp. 2+3): additionally quiet control group, Exp. 3) gender of speaker switched (female speaker: standard, male speaker: deviant)	Three sound conditions for foreknowledge, each conveying sentences of various types (e.g., aphorism, cooking recipe): Normal, 70 ms (sequence segmented into 70 ms chunks and reversed within each segment [50% intelligible], 140 ms (sequence segmented into 140 ms chunks and reversed within each segment. For post-foreknowledge, speech was presented at full intelligibility (e.g., normal)
Speech Intelligibility			Normal, 50% intelligible, and unintelligible
Level	Exp.1+3-4) spoken letters: 65dB(A); Exp.2) 52 sinusoid tones of 13 frequencies		
Performance	Visual task: digits presented to remember	Exp.1) Digit sequence visually presented for either serial recall or mental arithmetic task, before each trial indicated which task to do, Exp 2) mixed design, one group per task, mental arithmetic task workload increased by adding dual-task design (delayed recall of word-pairs)	Participants undertook a visual-verbal serial recall task
Task Load	Digits with low or high Gaussian noise overlayed		
Distraction	Task-irrelevant sound: spoken letters with oddball design	Irrelevant auditory sequence during task	Spoken sentential distractors
Perceived Disturbance			
Additional Information*	Subjective confidence judgments after each trial about participants performance		Speech was presented at different intelligibility levels only during the foreknowledge period

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[43] Kim et al. (2021)	[44] Kolbeinsson et al. (2022)	[45] Krasich et al. (2021)
Sample	38 participants (22 female, 20.7 ± 2.9 years old, range 18-31 years)	81 participants (41 male, 2 non-binary, mean age: 25.66 years old, range 18-58)	75 university students (58 female, 19.9 ± 1.6 years old)
Result	Reaction time towards the high-value auditory stimulus was decreased compared to low- or no-value stimulus. This effect was shown in both training and testing phases, suggesting attentional bias for reward-associated auditory stimuli even if those are task-irrelevant (distractors)	Prior information (negative vs. positive task instructions about sound) influences the perceived valence of distracting background sounds. Participants in the negative information group used more suppressing emotion regulation strategies to cope with the distraction. There was no difference in regard to annoyance, loudness, or arousal ratings, as well as cognitive performance in the serial recall task	Music had no impact on the gaze behavior of the participants, but it increased memory performance compared to the no-music condition
Sound Quality	Auditory stimuli: spoken letters monaural presentation (U,I,O), contralateral ear spoken numbers (1-4)	Task-irrelevant pink noise presented on 50% of the trials, sound rated as "neutral"	Three sound conditions: no music vs. classical music vs. modern-classical music
Speech Intelligibility			
Level	~56 dB	68dBA	
Performance	Training phase: listen for letter and press respective key on keyboard, correct responses monetarily rewarded, value of reward indicated with pure tones. Test phase: listen for numbers and press respective key on keyboard	Serial recall task with digits 1-9	Memory test of visual scenes (real-world urban scenes), vignettes presented of study scenes or foil images
Task Load	Possible reward differed between the three letters: high (20 cents), low (4 cents), or no reward (0 cents), associated letters counterbalanced between participants		
Distraction	Training phase: numbers as distractors, test phase: letters as distractors		Sound conditions presented during encoding of visual scene
Perceived Disturbance		Participants rated sound on four dimensions: valence (negative vs. positive), arousal (calming vs. agitating), annoyance (not at all vs. extremely annoying), and loudness (barely audible vs. extremely loud) on Visual analogue scale (VAS) from 0-100	
Additional Information*		Emotion regulation strategy assessed using State Emotion Regulation Inventory (SERI), Task instruction was different between two groups: one received negative information ("irritating" and "unpleasant" sound), one received positive information ("calming" and "pleasant" sound)	Eye tracking measured

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[46] Lagarrigue et al. (2021)	[48] Leist et al. (2022b)	[49] Leiva et al. (2021)	[51] Littlefair et al. (2022)
Sample	60 right-handed adults (undergraduate students, 32 females), 18 to 30 years (mean age = 21.80 ± 2.53)	83 adults (50 female, range 19-32 years), 81 third-grade children (44 female, 8.8 ± 0.75 years old)	204 adults (56 males) forming two age groups: 108 young adults (M age = 21.62, SD = 3.68) and 96 older adults (M age = 67.11, SD = 8.38)	Exp 1 (192 participants; 113 female; mean age = 23 years); Exp 2 (188 participants; 122 female; mean age = 25 years). Participants reported English as their first language
Result	Using rhythmic auditory stimulations (RegAud) and congruent audio-visual (CongrAV) stimulations procedural learning is enhanced. On the contrary, auditory stimulations with irregular or very quick tempo alter learning, potentially due to a distractor effect	Irrelevant Speech effect (ISE) from changing-state sequence detected in both age groups in the verbal task, but not in the spatial task. This suggests similarity-based interference, contrary to the attention-capture and changing-state hypothesis of ISE	When controlling for age-related differences in response time, older adults show greater deviance distraction from a visual stimulus caused by an unexpected sound compared to young adults (effect is nearly doubled reaction times)	Exp 1. A combined deviant (acoustic and categorical) was more disruptive of visual-verbal serial recall than a single deviant (acoustic or categorical); Exp 2. Habituation (reduction in disruption over time) was observed for acoustic deviants, but not for semantic, nor combined, deviants
Sound Quality	Six conditions: Visual Only (VisOnly), Congruent Audio-Visual (CongrAV), Non-Congruent Audio-Visual (NonCongrAV), Regular Rhythmic Auditory Stimulations (RegAud), Irregular Rhythmic Auditory Stimulations (IrregAud), Quick Regular Rhythmic Auditory Stimulations (FastRhyth)	Three sound conditions: silence vs. Irrelevant speech sound stream: consonant-vowel syllables, female speaker, either presented as changing-state trial (random sequence) or as steady-state trials (only syllable /ba:/ repeated)	600 Hz sinetone (standard) and white noise or environmental sounds (deviant)	To-be-ignored sequences comprised of sequences of letters. Standard trials did not contain a deviant. Deviants were acoustic (change in voice), categorical (change from a letter to a digit) or acoustic and categorical (the deviant digit was presented in a different voice)
Speech Intelligibility				
Level	CongrAV, NonCongrAV, RegAud, IrregAud and FastRhyth conditions: 500Hz, 100ms sinewave presented at 80dB	speech signals LA,eq = 62 dB	75 dB SPL	
Performance	Test of Attentional Performance (TAP), Serial Reaction Time Task (visuo-motor sequence learning)	Serial order reconstruction task (verbal or spatial task)	Proportional measure of distraction (PMD) was analysed based on binary classification of visual stimulus, preceded by an auditory distractor	Participants performed the visual-verbal serial recall task
Task Load				
Distraction				
Perceived Disturbance				
Additional Information*			Re-analysis of four studies, now controlling for age-related differences in reaction times	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[53] Luo et al. (2021)	[54] Luo et al. (2022)	[55] Manghisi et al. (2022)	[56] Marcenaro et al. (2021)
Sample	71 university students (43 females, mean age: 19.15 years SD=1.24)	71 university students (43 females, mean age: 19.15 years SD=1.24)	24 participants (8 female, 27.17 ± 6.14 years old, range 23-51 years)	21 subjects (13 males, mean age: 25.3 years, range 20-31 years, SD=3.1); 10 control subjects (6 males, mean age: 30.3 years, range 23-42 years, SD=5.7)
Result	Psychological well-being and flow state improved in intervention group, while it remained stable in control group. For the attention measure, the intervention group only improved in the ability to achieve and maintain an alert state but did not differ from the control group otherwise	Participants in nature sound condition exceeded in all deep learning, academic procrastination, and self-efficacy compared to the non-intervention group	No adverse effect of sound conditions on the cognitive performance of participants. Subjective workload ratings significantly worsened with increasing noise level	Mean reaction times for high and low task load different. However, no impact of sound was observed on the behavioural data (hit rates). Contralateral stimulation during visual WM task suppressed DPOAEs, suggesting moderating effect of selective attention and WM on the auditory pathway (medial olivocochlear reflex)
Sound Quality	Subjects in intervention group were required to use mobile app for at least 30 minutes per day. They played nature sounds when completing academic work during 4-week intervention. Control group received no intervention	Nature sound condition vs. no intervention condition. Nature sounds: computer-simulated sounds of birds, rainfall, waves, or wind	Three sound conditions: quiet environment vs. attenuated noise vs. full noise; noise source= signal generated by a pressure washer, modelled in building environment (cylindrical steel silo)	Primary tones (f1, f2) optimised to elicit distortion product otoacoustic emissions (DPOAE) presented to one ear during the visual detection task, distractor noise presented to contralateral ear
Speech Intelligibility				
Level			Quiet environment = 50 dBA; attenuated noise = 70 dBA; full noise = 85 dBA	f1: 65 dB SPL, f2: 55 dB SPL
Performance	Cognitive Flow State (flow short scale), Attention performance (ANT), and WM performance (2-back task)	No performance measures	N-back task	Visual change detection paradigm with congruent ipsi- or contralateral auditory stimulation: primary tones f1 and f2
Task Load			Low = 1-back task; high = 2-back task, subjective cognitive load assessed using NOISE TLX (modified version of NASA TLX)	Two load levels in visual task: low load (two objects) vs. high load (four objects)
Distraction			Sound conditions	Task-irrelevant distractor tones (broadband noise) presented contralateral to DPOAE eliciting tones
Perceived Disturbance				
Additional Information*	Psychological well-being assessed using PANAS	Subjective assessment of 1) Engagement in Deep Learning, 2) Academic Procrastination 3) Academic Self-Efficacy and weekly questionnaires		EEG and distortion product otoacoustic emissions (DPOAE) were measured to investigate modulation of medial olivocochlear reflex during selective attention and WM tasks

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[57] Marsh et al. (2023)	[61] Meng et al. (2021)	[63] Mones et al. (2022)	[65] Nagaraj (2021)
Sample	Exp 1) Thirty students. Exp 2) Thirty students - reduced to twenty seven (three at ceiling)	41 college students (18 females, mean age: 24.43 years SD=2.47)	51 university students online (21 male, 20.80 ± 1.15 years old, range 18-23)	53 adults with normal hearing (age 18-37 [M=22.5]), no cognitive impairments, native monolingual speakers of American English
Result	Changing-state sequences produce greater disruption than steady-state sequences on serial recall, but not the missing-item task	1) Main effect of sound condition on reaction time (reaction times longest in the presence of background speech and shortest in the presence of music) 2) increase in dBA levels decreased accuracy of location recall 3) increase in reverberation times improves reaction time and accuracy in shape recall 4) personality and noise sensitivity moderate effect of sound condition on visual cognitive performance	Compared to silence, participants gave more but not better (i.e., more original) answers during ambient sound stimulation. This effect was moderated by the participants level of cognitive flexibility, where more cognitive flexible participants gave more ideas in the AUT task	Listening comprehension for inferences was better in the noise condition compared to quiet condition, WM and AS processing times were also faster in noise condition compared to quiet condition, but more errors were made during this rapid switching in noise
Sound Quality	Exp 1 and 2. Non distractor vs. Steady-state vs. changing-state sequences of letters (a and b)	Five sound conditions: speech (Chinese language recording of an architectural design introduction; n.b. participants were also Chinese), traffic noise, air-conditioning noise, music (with no obvious conveyance of emotion), natural sound (a flowing river)	Two sound conditions: silence vs. ambient sound for AUT task	Noise and quiet condition
Speech Intelligibility				International Collegium for Rehabilitative Audiology (ICRA) noise as distractor, speech stimuli were digits and monosyllabic words in isolation (stimuli duration: 500ms)
Level		SPL: traffic and air-conditioning noise 45 dBA, 50 dBA, 55 dBA, 60 dBA, 65 dBA; Reverberation time values: speech and music 0.3 s, 0.6 s, 0.9 s, 1.2 s, 1.5 s	60% volume level, corresponding to approximately 65dB	65 dB SPL, SNR 90% Intelligibility determined on individual level for each participant
Performance	Visual-verbal serial recall in Exp 1, and recall of a missing-item from a visual-verbal sequence in Exp 2	Visual detection task with recall of target shape and location (reaction times and accuracy measured)	Cognitive flexibility using Dimensional Change Card Sort task (DCCS) and divergent thinking using the Alternative uses Task assessed	Forward and backward digit span task, Auditory Attention Switching task (AS), auditory WM task, listening comprehension
Task Load				Noise was used as a distractor to increase the cognitive load while performing cognitive and speech tests
Distraction	Speech conditions	Sound conditions during task performance		
Perceived Disturbance				
Additional Information*		Personality Extraversion test: Eysenck Personality Test E-Scale; Noise Sensitivity: Weinstein Noise Sensitivity Scale		

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[67] Parmentier et al. (2022)	[68] Pascoe et al. (2022)	[69] Pedale et al. (2021)	[70] Pérez-Bellido et al. (2023)
Sample	32 university students (23 female, 19.03 ± 1.24 years old, range 18-23)	67 university students (22 male, 21.06 ± 1.82 years old, range 18-29)	23 young children (11 female, 6.2 ± 0.5 years old, range 5-7 years), 32 older children (16 female, 10.2 ± 0.4 years old, range 10-11 years), 30 young adults (23 female, 22.2 ± 1.7 years old, range 20-27 years), 30 older adults (15 female, 71.7 ± 5.3 years old, range 62-86 years)	Exp. 1) 25 participants (17 female, 24 ± 6 years old); Exp. 2) 25 participants (12 female, 25 ± 7 years old)
Result	Performance in response to a deviant after a previous Go-trial was enhanced compared to a standard tone presentation, but decreased after a NoGo-trial. Performance in response to silence was slowed in both conditions, suggesting functionally distinct behavioural effects between deviance distraction and removal of unspecific warning signals	There was no effect of background music on Stroop test performance compared to silence. White noise negatively affected conflict processing (incongruent trials), potentially due to inducing negative emotions	Accuracy and reaction times in the visual search task follow a u-shaped distribution, with increasing and decreasing performance with increasing age until accuracy and reaction times respectively drop and rise in older adults. All age groups were affected similarly by the spatial cue: participants showed better performance in the cued condition compared to the neutral condition, and compared to the uncued condition. Furthermore, the shorter the SOA, the more affected participants' performance was. These effects were predominantly shown in the extreme age groups compared to young adults and older children	Participants' performance was enhanced in the audiovisual condition compared to visual only. They were more likely to report a target with sound stimulation. This behavioural effect is supported by dynamic processing models based on the MEG data, suggesting that sound-induced visual sensitivity enhancement is induced through top-down modulation of late-stage sensory maintenance
Sound Quality	Three sound conditions: standard (600Hz sine wave tone, 80% of trials) vs. deviant (burst of white noise, 10%) vs. silent (no tone, 10%)	Three sound conditions: white noise vs. classical music vs. silence	Auditory spatial cue (white noise burst) before presentation of scene; manipulations: location = left, right, or both sides (this cue was not informative of target location); SOA: 50 ms (SOA50 condition), 200 ms (SOA200 condition), or 500 ms (SOA500 condition)	Target presentation in visual detection task accompanied with 1000Hz pure tone (33ms) on 50% of the trials
Speech Intelligibility				
Level	75dB SPL	Individually set to be "moderate intensity"	Sound pressure level individually adjusted to "clearly audible" level, 62 dB on average; range 58-70 dB	70 dB
Performance	Go-NoGo task (GNG) using digit categorization (Go) and fixation cross presentation (NoGo), trials cued with task-irrelevant oddball sound	Stroop test and Wisconsin card sorting test (WCST) before and after sound exposure	Visual search task for "agentive" element (i.e., animal or human) in either internal (e.g., kitchen, bathroom)or external scene (e.g., garden, street)	Visual detection task, Exp.1) participants had to detect change of stimulus from placeholder to target (S+) or no change (S-) either in central fixation spot or in the periphery. Exp.2) participants had to ignore target and sounds, and memorise and report colour change of fixation cross
Task Load				
Distraction	Auditory oddball			Exp.2) audiovisual target serves as distractor
Perceived Disturbance				
Additional Information*				MEG measured

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[71] Pérez-Hernández et al. (2021)	[72] Perham et al. (2023)	[74] Prutean et al. (2022)
Sample	18 mothers (9 second time mothers [SM], mean age: 30.22 years SD= 5.60; 9 first time mothers [FM], mean age: 28.44 years SD=3.67)	30 native English-speaking participants (8 female, 22 male) aged between 18 and 30 years old	Exp.1) 24 university students (3 male, 19.58 ± 2.60 years old), Exp.2) 48 university students (standard group: 4 males, 20.17 ± 1.97 years old; standard/deviant group: 7 males, 20.83 ± 2.92 years old)
Result	SM needed less time to solve the task while emotional stimulus was presented compared to FM and compared to their performance in the white noise condition. Both groups indicate higher arousal and alertness during crying-condition. FM recruited more cognitive resources compared to SM as indicated by increased coupling between prefrontal and parietal areas	A semantic deviant (change in taxonomic category) within an otherwise semantically homogenous to-be-ignored sequence, impaired free recall for the visual item the deviant accompanied, and the one after. Further, in a suprise recognition test for previously to-be-ignored items, participants demonstrated better memory for deviant than non-deviant items	Presentation of a deviant oddball sound reduced the expression of sequence learning on the following trial (oddball-dependent sequence effect, OSE), potentially due to the attentional control towards the oddball
Sound Quality	Two high-fidelity auditory recordings presented concurrently during task performance: emotional stimulus = infant crying, neutral stimulus = white noise with comparable intensity to crying	Sequences comprised 9-words sampled from a single semantic category (e.g., "Birds", "Fruit")	Exp.1) standard oddball tone = 150-ms sine wave tone, 600 Hz frequency; deviant oddball tone = 150-ms sine wave tone, 710 Hz frequency, on 20% of trials, Exp.2) deviant sine wave replaced by white noise
Speech Intelligibility			
Level	Crying: 53.6dB, white noise: 54 dB	Between 65-75 dBA	
Performance	Visuospatial working memory (vsWM) task (Corsi block-tapping task: accuracy, latency to first movement LM, total execution time TET, longest sequence)	Free recall of visual-verbal lists comprising 3 words from 3 different semantic categories. Surprise recognition test for to-be-ignored items	Exp.1) cross-modal serial reaction time (SRT)-oddball task: visual SRT with 12 target locations, target trial preceded by irrelevant standard sound, then after learning phase: training or control trial, preceded by either standard or deviant sound; Exp. 2) one group SRT only with standard tones, one group with deviants
Task Load			
Distraction	Emotional vs. neutral auditory stimulation		Auditory oddball
Perceived Disturbance	Manikin Self-Assessment Scale immediately after WM task		
Additional Information*	EEG measured		

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[75] Radun et al. (2020)	[78] Rakhshan et al. (2022)	[79] Richardson et al. (2022)
Sample	59 participants (38 female, mean age 25.2 years, range 19-42)	31 healthy right-handed subjects (14 male, 30.84 ± 6.16 years old)	96 participants (59 female, 37 male), Mean age = 24 years (SD = 4). English reported as first language
Result	Speech, in comparison to silence, significantly increased workload, annoyance, and physiological stress (decreased HRV, increase in cortisol), even though it was deemed less tiring. Speech, in comparison to noise, significantly increased workload, annoyance, decreased fatigue, and physiological stress (decrease in HRV). Noise, in comparison to silence, significantly increased annoyance and physiological stress (cortisol levels), whereas workload and fatigue were not significantly increased. Speech and noise impaired n-3-back performance compared to quiet, but speech and noise did not differ. For the serial recall tasks, sound interacted with serial position such that speech, compared to quiet, disrupted memory performance for final items within the sequence	Alpha binaural beats (10Hz BB) improved reaction times and -variability and reduces decline of performance in the visuospatial modality, as well as in the auditory-verbal modality (although to a lesser extent). Loudness affects reaction times negatively	Participants presented with sequences comprising a non-dominant homophone and its associates, or just the associates of the homophone, in to-be-ignored sequences, later spelt the homophone in accordance with its non-dominant meaning to a greater extent if the "priming" speech was intelligible (e.g., not reverse speech)
Sound Quality	Three noise conditions: silence, noise (pseudorandom pink noise), speech (radio broadcast)	5 within-subjects sound conditions: stimulation with 10Hz, 16 Hz,40 Hz binaural beats, 240 Hz pure tone and silence	To-be-ignored sequences comprised meaningful or meaningless (reversed) speech that comprised either sequences that contained a non-dominant homophone and its associates, or merely associates of the non-dominant homophone
Speech Intelligibility	Speech condition: STI 0.9		Sequences were intelligible (normal speech) or non-intelligible (reversed speech)
Level	Silence: LA5-LA95b =1.0 dB; LAeqc =35 dB; noise: LA5-LA95b =1.0 dB; LAeqc = 65 dB; speech: LA5-LA95b = 24.2 dB; LAeqc =65 dB	Loudness individually determined as maximum loudness that can be tolerated comfortably	
Performance	N-back task (n: 0-3), Auditory serial recall (ASR), visual serial recall (VSR)	Dual 2-back task with feedback, one task in visuospatial modality (object shape changes location) and a concurrent task in the auditory-verbal modality (verbal presentation of digits)	Participants initially undertook a visual-verbal serial recall with spoken distracters and thereafter undertook a spelling task
Task Load	Subjective rating scale of workload: 0-10		
Distraction	Background pink noise, background speech		
Perceived Disturbance	Subjective rating scale of perceived fatigue: Swedish Occupational Fatigue Inventory (SOFI), baseline stress level measured with Perceived Stress Scale (PSS-10)		
Additional Information*	Annoyance: Subjective rating scale of annoyance: 0-10; Groups were balanced based on Weinstein's 21-item noise sensitivity scale, Personality measured (Short Five, S5), and physiological stress measures (Cortisol, Noradrenaline; Blood pressure, HRV)	32-channel EEG recorded	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[80] Ríos-López et al. (2021)	[81] Röer et al. (2022)	[82] Sadeghian et al. (2021)
Sample	41 german native speakers (27± 6.8 years old, range 18-45 years)	252 subjects (180 female, 24 ± 7 years old). four different language samples	120 healthy adults (60 females, range 20-35 years)
Result	Influence of language of background speech was not visible at the behavioural level, but was in the pupillometry data. Here, subject's pupil size increased more in the non-meaningful (French) condition compared to meaningless background speech (German), suggesting increased mental effort and attentional resource allocation in the meaningful speech condition	Unexpected to-be-ignored background speech negatively impacts cognitive performance the most, compared to expected background speech and silence. This semantic mismatch effect was successfully replicated across four different language samples	Linear decrease of response rate and increase for reaction time for all psychophysical parameters per increase in difficulty level of n-back task. Increasing loudness and roughness is associated with increasing annoyance, as well as fatigue, together with fluctuation strength
Sound Quality	Background stimulation, to-be-ignored: either French or German short story	Auditory distractors: 24 proverbs as expected or unexpected condition, vs silent condition	16 noise signals were broadcast while participants performed n-back task with differing difficulty-levels
Speech Intelligibility		Presented binaurally at a normal conversational speech level	
Level	67.5 dB SPL		16 noise signals (background level 40 dB): four loudness levels (2.98 – 8.25 Sone), four noise roughness levels (0.7-1.25 Asper), four sharpness of the noise levels (1.54-2.52 acum), four fluctuation strength levels (0.36-1.41 vasil)
Performance	Auditory oddball discrimination task using animal sounds, discriminate between long or short sounds. Standard stimuli: 80% of trials one animal (short or long), deviant: 20% other animal (short or long)	Standard serial recall task with eight digits	N-back task
Task Load			Three difficulty-levels: manipulating load factor n and adding feature; assessed with NASA-TLX
Distraction	Background speech stimulation: french = foreign language, non-meaningful condition; german = native language, meaningful sound condition	Expected condition: proverbs ended with semantically correct word; unexpected condition: proverbs ended with semantically incorrect word (=violation of semantic expectations)	
Perceived Disturbance	Subjective rating under which language condition the task was easier to complete		
Additional Information*	Pupil data measured		Annoyance: Measured by EEG as an increase in PrTeta and PrAlpha. increase in loudness was significantly associated with an increase in annoyance and roughness; EEG recordings

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[83] Salagovic et al. (2020)	[84] Samper et al. (2021)	[87] Schirmer et al. (2020)
Sample	Exp.1) 15 university students (14 female, mean age: 19.7 years old); Exp.2) 16 university students (12 female, mean age: 20.4 years old)	Exp.1) 25 university students (18 female, mean 19.25 years old); Exp.2) 26 university students (17 female, mean 19.65 years old); Exp.3) 24 university students (19 female, mean 19.83 years old); Exp.4) 96 university students (67 female, mean 19.42 years old)	64 participants (32 female, 24 ± 4 years old, range 18-28 years)
Result	Interaction effect for response time: cueing with task-irrelevant tone improved reaction time in the incongruent condition more compared to other flanker conditions, suggesting general alerting benefits, which in turn are reduced through the incongruency manipulation	Irrelevant sound effect persists even in condition wherein rehearsal strategies are unlikely to be applied. ISE is not differently affected by random, changing-state IS sequence compared to a steady-state IS sequence, opposing researsal-disruption accounts of ISE in favour of an attention-disruption model	Behaviorally, participants reacted faster when exposed to highly metrical background sounds compared to low metrical sounds, as well as to high regularity compared to low regularity. Other behavioural effects were not found, as e.g., the target timing had no effect on reaction times. Early processing was facilitated in the high background regularity condition across metrically aligned and misaligned positions, opposing the notion that metrical entrainment causes synchronised cross-modal attentional effects, but rather external rhythms
Sound Quality	50% of the trials an auditory cue was presented 100ms before onset of visual task (presentation of letters in Flanker task)	Exp. 1+2+4) Two sound conditions: memory span task in silence vs. memory span task with auditory IS sequence (random spoken digits); Exp. 3) additionally included "steady-state" IS condition: same digit repeated throughout trial	Background rhythms with either high vs low metricality and with high vs low regularity vs. silent periods
Speech Intelligibility			
Level	Auditory cue = sine tone; 500 Hz, 20ms duration, 65 dB. presented binaurally	Irrelevant Sound sequence: spoken digits 1-4, 350 ms stimulus, 150 ms ISI	~65 dB
Performance	Detection of target letters	Running memory span task, presented stimuli had to be recalled in correct order. Exp. 1-3: stimuli = letters; Exp. 4: stimuli = monosyllabic words	Visual detection task: detect colour change of fixation cross, colour changes metrically aligned or misaligned in temporal order with background rhythm
Task Load	Exp.1) Congruency conditions: stimuli-congruent = targets and distractors same letter, same button press; response congruent = targets and distractors different letter, same button press; incongruent = targets and distractors different letter, different button press. Exp.2) included neutral condition = flanker letter which has no button assigned and is never target; and stimuli-congruent + incongruent condition	Exp.1) Fast presentation of letter sequence or slow presentation; Exp.2, 3, & 4) two blocks of only fast presentation	
Distraction	Visual distractors in task (=flanking letters)	Irrelevant Sound stimuli sequence	Background music
Perceived Disturbance			
Additional Information*		After each block questionnaire about rehearsal strategy	61-channel EEG recording

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[89] Shibuya et al. (2022)	[91] Simal et al. (2021)	[92] Soh et al. (2020)
Sample	16 students (6 female, range 21-24 years old)	32 participants (6 male, 21.7 ± 3.0 years old)	Exp.1) 21 college students (14 female, 19.05 ± 1.12 years old); Exp.2) 21 college students (11 female, 20.52 ± 2.14 years old)
Result	Cognitive performance was not affected by the sound conditions, but participants rated the change sound level condition as more relaxing (i.e., listening to high level music during low effort (1-back) task). As task load increased, subjective ratings indicated a need to reduce the sound level	Performance on the TOJ task was positively influenced by auditory cue on visual presentation side, as supported by an increased ACOP amplitude suggesting faster processing of co-localized visual stimuli	Unexpected sounds lead to a suppression of SSVEP amplitudes to both attended and unattended visual stimuli, executive inhibitory control affected by distractor sounds, even though there was no difference between expected and unexpected condition on behavioural level (reaction time)
Sound Quality	Four sound conditions: High sound level vs. middle sound level vs. low sound level vs. change sound level (sound level adapted based on task load: high for 1-back test, middle for 2-back test, and low for 3-back test), auditory stimulus: background music (J-Pop-, Ghibli-, Disney-song piano versions)	Cue: burst of pink noise on two possible locations: 20° to left or to the right of central fixation cross on screen	Exp 1) in 20% of trials unexpected bird sounds were presented in delay period between stimulus presentation and target onset (=unexpected condition); in rest no sounds were played (=expected condition); Exp 2) every trial included a sound to control for sound-induced effects in Exp 1
Speech Intelligibility			
Level		500 Hz-15kHz; 80 dB	Exp 1) bird sounds: SPL to conversational level; Exp 2) 600-Hz sine wave tone of 200-ms duration
Performance	N-back task	Temporal order judgments (TOJ) task: sound presentation, then after short or long delay: presentation of visual stimuli; task: determine which stimuli appeared first (or last)	Cross-Modal steady-state visual evoked potentials (SSVEP) Oddball Task : cued attention with target detection task
Task Load	Low = 1-back task; middle= 2-back task, high = 3-back task		
Distraction			Unexpected bird sounds
Perceived Disturbance			
Additional Information*	Annoyance: Subjective feeling of task (e.g., difficulty, length...) on 7-point scale	Effect of cueing on auditory-evoked contralateral occipital positivity (ACOP) measured using EEG, ACOP= event-related evoked in visual cortex by contralateral salient auditory stimulus	62-channel EEG recording

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[93] Song et al. (2022)	[94] Stobbe et al. (2022)	[96] Szychowska et al. (2021)
Sample	60 university students (38 female)	295 online participants; 83 traffic noise low (45 male, 20.7 ± 7.48 years old), 69 traffic noise high (44 male, 25.7 ± 7.1 years old), 63 birdsong low (45 male, 26.5 ± 6.30 years old), 80 birdsong high (43 male, 28.7 ± 7.72 years old)	33 participants (13 male, 27.09 ± 5.11 years old, range 18-40 years)
Result	Increased noise sensitivity was positively correlated with neuroticism and negatively correlated with conscientiousness. There was a significant interaction between noise condition and noise sensitivity for cognitive performance and annoyance, where accuracy and annoyance ratings were the same for both groups in the quiet condition, but the low sensitivity group dropped more in performance for the road traffic noise and even further for speech noise compared to the high sensitivity group	No effects of sound condition or time were found for cognitive performance. Exposure to high diversity bird sounds decreased depression scores, and exposure to either bird sound condition decreased anxiety and paranoia ratings	Participants performance increased during low-load compared to high-load condition, whereas workload ratings were higher for high-load compared to low-load. Bayesian analysis indicates auditory steady-state responses (ASSRs) to 20Hz, 40Hz, and 80Hz show no effect of visual work-load, suggesting that the adaptive filtering model of attention does not apply to crossmodal attention
Sound Quality	Three sound conditions: quiet vs. road traffic noise vs. speech noise	Four sound conditions: 1) low diversity birdsong (two species) vs. 2) high diversity birdsong (eight species) vs. 3) low diversity traffic noise (eight car recordings) vs. 4) high diversity traffic noise (car recordings, sirens, construction, trucks, airplane,...)	20-, 40-, and 80-Hz amplitude-modulated tones targeting different processing stages of the auditory pathway
Speech Intelligibility	Speech condition: meaningful but task-irrelevant dialogue		
Level	Quiet condition = 35dB background lab noise, road traffic = 70dB, speech noise = 70dB	Headphone loudness level set to 80%	Binaurally at 60 dB SL
Performance	2-back task	Digit span cognitive performance and dual n-back task (auditory letter presentation, visual shapes presentation)	Visual detection task: series of letters, varying in name, colour, and capitalization; participants responded to either feature and ignore background sounds
Task Load		2- and 3-back task	Three different load conditions: passive viewing of letters (no load) vs. detecting targets based on color (low load) vs. detecting targets based on name and colour (high load). Subjective workload assessed with NASA-Task Load Index (TLX) using the Borg centiMax (CR100) scale
Distraction	Sound conditions		Background sounds
Perceived Disturbance			
Additional Information*	Annoyance: Noise annoyance scale measured according to ISO/TS15666 standard (10-point self-rating); Groups selected based on noise sensitivity (low vs. high, determined with Revised Weinstein Noise Sensitivity Scale), personality measured using NEO Five-Factor Inventory (NEO-FFI)	Annoyance: Diversity/monotony, pleasantness, and beauty of soundscape assessed on 0-100 Visual Analogue Scale; Depressive symptoms (Community Assessment of Psychic Experiences (CAPE)), mood (State Trait Anxiety Depression Inventory (STADI)), paranoia (short version of paranoia checklist)	6-channel EEG measured

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[97] Teodoro et al. (2022)	[99] Turoman et al. (2021)	[100] Wang et al. (2021)
Sample	19 patients with Functional Cognitive Disorder (FCD, 17 female, 51 ± 9 years old), 23 healthy control (HC, 12 female, 49± 10 years old)	39 adults with normal or corrected-to-normal vision and normal hearing (5 left-handed, 14 males, M age : 27.5 years, SD: 4 years, range: 22-38 years)	Exp 1) 44 university students (30 females, 19.3 ± 1.20 years old); Exp 2) 41 university students (28 females, 19.51 ± 1.08 years old)
Result	FCD patients consistently show increased reaction time compared to healthy control, regardless of task difficulty. This effect was not significant anymore after adjusting for confounders. Accuracy did not differ between groups, as well as EEG-biomarkers of mental workload (P300). Subjective ratings of mental workload differed significantly, especially in noisy conditions, even though there was no effect of noise or task difficulty on accuracy in the patient or control group, suggesting a deficit in global metacognition, but not in task-specific metacognition for patients	Multisensory enhancement of attentional capture (MSE) was present in the audiovisual distractor condition, as compared to visual only	Reaction times in the speech production condition and irrelevant background sound condition were significantly shorter compared to no speech or no background speech conditions. This could either be due to the facilitation of interference processes via the interruption of the phonological store device, but could also be due to the allocation of more attentional resources due to increased task demand in the dual-tasks
Sound Quality	Auditory oddball task: standard tone (500Hz) and deviant (2000Hz tone)	4 conditions: matching/non-matching visual distractor with our without auditory stimulus accompanying onset of distractor	Exp 1) two speech conditions: no speech (normal) vs. speech production (articulatory suppression condition, participants were continuously repeating the word "Coca-Cola" out loud while performing inference task); Exp. 2) two sound conditions: no sound vs. task-irrelevant background speech
Speech Intelligibility			
Level		80dB SPL	Exp. 2) male speaker presenting Chinese classic novel, presented at 46.79-78.48 dB
Performance	Modified Stroop colour-word task with five conditions based on task load: 1) Condition 0–oddball: passive listening to oddball; 2) Condition 1–SCWT congruent silent; 3) Condition 2–SCWT congruent noisy; 4) Condition 3–SCWT incongruent silent; 5) Condition 4–SCWT incongruent noisy; 6) 'Condition 5–SCWT incongruent count (active listening, count occurance of deviants)	Visual target detection task, with visual distractor, distractor onset in 50% of trials accompanied with auditory stimulus. Reaction time, spatial cueing effects and error rates per condition were analysed.	Reading comprehension of correct inference based on causal relationships presented in three sentences per trial with two conditions: inference (causal relationship present) vs. control (no causal relationship present)
Task Load	Varied by task difficulty: congruent vs. incongruent, presence or absence of auditory oddball task, and active or passive listening to auditory oddball task if present; after each condition, participants rated workload using NASA-TLX		
Distraction	Presence or absence of auditory oddball task		Speech and sound conditions
Perceived Disturbance			
Additional Information*	Assessment of memory functions (five-point Subjective Memory Complaints Likert scale, 'short' and 'long' versions of functional memory disorder inventories), fatigue/sleep (Chalder Fatigue Scale, Jenkins Sleep Scale), and psychological symptoms (Generalized Anxiety Disorder-7 scale, Obsessive-Compulsive Inventory (OCI), painDETECT questionnaire, PHQ-9, Somatoform Dissociation Questionnaire-20); EEG measured (P300 as biomarker for mental workload)	129-channel EEG recording analysing N2pc component	

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ categor

Author	[101] Wang et al. (2022)	[102] Wang et al. (2021)	[103] Wang et al. (2022)
Sample	60 male participants (15Hz binaural group: 23.27 ± 3.90 years old; 40Hz binaural group: 20.80 ± 2.40 years old; relaxing music group: 20.47 ± 2.00 years old; 240Hz pure tone group: 23.20 ± 3.61 years old)	36 participants (24 female, 20.83 ± 2.01 years old, range 19-28 years)	40 participants (18 female, 22.64 ± 2.60 years old)
Result	No significant differences between groups in performance measure (PVT). Accuracy in the TloadDback task dropped for the 40Hz BB and relaxing music group, while it stayed constant for the other groups (15 Hz and 240Hz pure tone group). All groups were more fatigued after task manipulation, 40Hz BB group most fatigued. BRUMS scores were all significantly increased after task manipulation in all groups. In the 240Hz pure tone group, increased functional connectivity in alpha and theta band suggest the increased need for recruitment of cognitive resources. On the contrary, 15Hz BB related to beta band increased node efficiency and decreased average path length, suggesting improvement of mental fatigue in this group	Synchronised auditory stimulation reduced the "attentional blink" in a rapid serial visual presentation paradigm. This effect was independent of the salience of the auditory stimulus and suggests that enhanced attentional recruitment during the cross-modal condition reduces AB	Cognitive performance significantly increased during the BB stimulation compared to pink noise stimulation during the visuospatial working memory task, as well as the verbal memory task, suggesting improvement of executive functions and potential entrainment as supported by the EEG recordings
Sound Quality	Four sound conditions: 15Hz binaural condition, 40Hz binaural condition, relaxing music condition, 240Hz pure tone condition	Exp.1) Three sound conditions: absent vs. synchronised with T2 vs. synchronised with all; three lag conditions: lag1 vs. lag2 vs. lag5; Exp.2) same as Exp 1 but only two sound conditions: no "synchronised with all" condition anymore	Two sound conditions: 40 Hz binaural beats (BB, L:400 Hz; R:440 Hz) vs. pink noise
Speech Intelligibility			
Level	SPL individually determined before start of formal experiment	Exp 1) Pure tones (1259 Hz) generated by a 75 dB sine wave; Exp.2) additionally low (300 Hz) tone	
Performance	Mental Fatigue-Inducing Task = improved TloadDback; performance assessed using psychomotor vigilance task (PVT) task before and after TloadDback task	Exp. 1) After presentation of visual (-auditory) stimulus stream of two target letters (second: attentional blink, AB hypothesised) and visual distractors, participants had to indicate which letter they saw first and which letter they saw second. Accuracy of first-letter detection (T1) and accuracy of second-letter detection given a correct first-letter detection in this stream (T2|T1); Exp.2) additionally accuracy of detecting high or low sound	Visuospatial working memory task (Delayed match-to-sample task); verbal working memory task (Word list recall task)
Task Load	"FatigueF assessed on Visual Analogue Scale (0-100, "Not at all fatigued" and "Extremely fatigued", respectively), and "Effort" with Intrinsic Motivation Inventory (IMI)		Increased by trial-by-trial procedure in delayed match-to-sample task (increase from two color-blocks to five color-blocks to match)
Distraction			
Perceived Disturbance			
Additional Information*	Annoyance: Before and after TloadDback task: Brunel Mood Scale (BRUMS) examining anger, depression, tension, and energy; 32-channel EEG recorded during task performance and resting state		64-channel EEG measured

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[104] Ward et al. (2021)	[105] Weichenberger et al. (2022)	[106] Whiting et al. (2021)
Sample	48 healthy young adults (7 male, 19.65 ± 1.59 years old) and 48 healthy older adults (8 male, 73.92 ± 5.80 years old)	15 participants (8 female, 26.5 ± 3.42 years old, 8 male, 24.43 ± 2.76 years old)	Exp.1) 37 university students (72% female, 20.11 ± 1.30 years old, range 18-22); Exp.2) 32 adolescents (50% female, mean: 15 years ols, range 15-18); 28 mid-life adults (61% female, mean: 48 years olds, range 37-68)
Result	Free recall was impaired in the incongruent condition in both groups compared to mood-matching stimulation. There was a main effect of WM performance, which was improved in both groups comparing matching condition against baseline, and matching condition against non-matching condition in both groups. Mood moderates the effect of music on cognitive performance	When ultrasound (US) was presented 10Hz below the hearing threshold, stronger activation in inferior frontal gyrus (IFG) during n-back task could be seen. Behaviorally, the increased IFG activation was associated with decreased reaction times for the n-back task, as well as lower pleasantness-ratings during resting-state fMRI, suggesting increased recruitment of cognitive resources when performing a task accompanied with unpleasant US	Adolescents are more affected by distractions caused by simulated phone notifications compared to mid-life adults. Their accuracy and reaction time in an arithmetic task decreased and increased significantly, respectively, in notification-trials compared to no notification-trials. Furthermore, HRV measures increased after distractor presentation. Response inhibition difficulties were associated with this increase in RT and HRV changes, suggesting increased reactivity of adolescents in regards to phone notification
Sound Quality	'Happy' and 'sad' music, respectively: mode (G-major vs. G-minor), tempo (fast BPM = 134 vs. slow BPM = 75), articulation (staccato vs. legato)	Three sound conditions: no-tone condition (NTC), above hearing threshold (ATC), below hearing threshold (BTC)	Sometimes distractor sound played during the presentation of math problem (sound = audio recording of vibration alert, simulating notification on phone)
Speech Intelligibility			
Level		ATC = 21.5 kHz ultrasound presented at 5dB above individual hearing threshold; BTC = 21.5 kHz ultrasound presented at 10dB below individual hearing threshold	62 SPL dBA
Performance	Free recall of 20 individual words and WM with (WAIS-III) Backward Digit Span task	Resting state fMRI collected with the three sound conditions as well as n-back task with the three sound conditions	Verify correctness of arithmetic task (one 2-digit number added to another 2-digit number), also response inhibition measured using Stroop task
Task Load			
Distraction		Sound conditions during n-back task	Audio recording of vibration alert, present in 24 of 144 trials (Exp. 1) or 20 of 120 trials (Exp.2)
Perceived Disturbance		After each run participants were asked if they heard the sound ("yes", "no", "unsure"). Then asked to rate pleasantness (scale -5 to 5) and affect on performance (if n-back run; scale -5 to 5)	
Additional Information*	Investigated influence of mood and congruent or incongruent music stimulation on free recall and WM	fMRI in resting state under sound conditions and with active task performance under sound conditions measured, as well as depressive symptoms (Beck Depression Inventory (BDI-II)), state- and trait-anxiety (State-Trait Anxiety Inventory (STAIX1/X2)), neuroticism (Big Five personality traits short-scale (BFI-S))	Compulsive cell phone use measured (12-item Compulsive Cell Phone Use questionnaire (CCQ)), as well as ECG (HRV)

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[107] Yang et al. (2022)	[108] Yang et al. (2021)	[109] Ylinen et al. (2022)
Sample	12 male students (23.25 ± 2.314 years)	92 participants (72 female, 19.1 ± 1.53 years old)	18 univ. students (9 female, mean: 25.6 years, range 19-39)
Result	With increasing SPL levels and sharpness, performance in the PVT decreased, suggesting impairment of human vigilance. This effect was also observed in HRV measures. Under low workload, increasing sharpness had a significant deteriorating and enhancing effect on the performance of the TRA and SYS, respectively. Therefore, research should also investigate sharpness next to SPL	There was an increased reaction to the affective startling noise (SR) when participants watched unpleasant pictures compared to unpleasant pictures. Furthermore, under high WM-load the SR was decreased. Also, categorization based on ECG measures (low vs. high vagally mediated heart rate variability) showed that low vmHRV is associated with higher impact of WM load on the attenuation of the affective SR modulation, suggesting top-down modulation of affective response through WM resource allocation	Lower quality only affected phonological processing, potentially due to ceiling effect after training session. Speech processing in noise recruits the same cognitive areas as speech-in-quiet. Areas involved in attentional control potentially are not necessary in ecologically valid experiments of speech processing. The phonological task additionally involved dorsal stream areas, as well as secondary somatosensory areas. Activation of orbitofrontal areas during the dialogue task underlines its function in social cognition. Therefore, involvement of neural networks of selective attention and speech processing is highly dependent on the task
Sound Quality	Three sound conditions with differing loudness and sharpness levels, subjects were exposed during entire experimental session: N85-S1, N80-S1, N75-S2	Auditory startle-eliciting stimulus = noise burst in half of the trials	1) Audiovisually presented dialogues between female and male speaker, 2) distractor: audiobook 3) noise-vocoding of speech streams via convolution with white noise (2 levels, good auditory quality vs. poor quality) 4) noise in visual information in dialogue: blurring of faces of speakers (2 levels, good visual quality vs. poor quality) 5) task to ignore both auditory streams: count rotation of fixation cross
Speech Intelligibility			Pilot study: 16 bands condition = average of 98.5% words correctly reproduced; 4 bands condition = average of 76.4% words correctly reproduced
Level	N85-S1 = 84.2 ± 0.8 dBA, 1.28 ± 0.03 acum; N80-S1 = 78.3 ± 0.7 dBA, 1.30 ± 0.03 acum; N75-S2 = 75.0 ± 0.8 dBA, 2.42 ± 0.04 acum	SR: 100-dBA broadband noise (20- 20,000 Hz)	Auditory noise: good auditory quality (fundamental frequency intact, 16 frequency bands noise-vocoded) vs. poor quality (fundamental frequency intact, 4 frequency bands noise-vocoded); SPL: appr. 80 dB SPL at the tip of the earphone
Performance	Psychomotor vigilance test (PVT) performed and three tasks of the Multi-Attribute Task Battery (MATB) = Tracking Task (TRA), System Monitoring Task (SYS), Resource Management Task (RES)	Sternberg memory task: memorise digits, then compare with probe digit if it was in the memorised digit sequence	Dialogue (S, semantic) task: percentage of correct answers; audiobook (P, phonological) and fixation cross count (V, visual) task: distance of participants answer from correct answer
Task Load	MATB tasks with three levels: low, medium and high mental workload, subjective task load measured using NASA-TLX Scale	Performance measure: high (5 digits memorised) vs. low (2 digits memorised)	
Distraction			S task = focus on dialogue, ignore audiobook; P task = focus on audiobook, ignore dialogue; V task = focus on visual stimuli (fixation cross change), ignore both dialogue and audiobook
Perceived Disturbance		Between digit sequence presentation and probe digit presentation, affective response-eliciting picture was shown (International Affective Picture System, IAPS)	
Additional Information*	Heart Rate Variability measured (ECG) and EEG	Electrocardiogram (ECG) and Electromyogram (EMG) recorded; resting vagally mediated heart rate variability (vmHRV) as moderator for auditory affective startling response	fMRI during task performance

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category

Author	[110] Yoo et al. (2022)	[112] Zhao et al. (2021)	[113] Zhou et al. (2022)
Sample	126 university students (70 music majors: 7 female, 23.0± 3.1 years old; 56 non-music majors: 7 female, 22.0 ± 2.5 years old)	29 participants (17 female, mean age 20.9 years, range 19-27 years)	48 healthy adults (24 males, mean age: 27.38 years, range 18-66 years, SD=12.34)
Result	There was an interaction between the music condition and group (music majors and non-music majors). Non-music majors were shown to be less affected by the different music conditions, as their performance levels stayed constant across arrangement type. Music majors however completed less items when listening to the original music condition compared to rhythm-only and melody-only. Complexity of the music predicted non-music majors cognitive performance, but not music-majors' performance. These findings suggest that background music does not affect cognitive performance, negatively or positively	Hit rates were poorer and reaction times were slower in the audiovisual condition compared to visual only, suggesting increased cognitive demand for filtering out the task-irrelevant auditory stimulus. The co-occurrence of stimuli in the audiovisual condition lead to an attentional spreading effect independent of visual stimulus location	The male group did not show a significant difference between noise groups or workload groups. The female group with the noise manipulation showed significantly higher scores in the high workload-noise group compared to the low workload-noise group. Workload also moderates the effect of noise in female groups
Sound Quality	Four background music conditions: original (Mozart's Piano Sonata); melody-only; rhythm-only; and no music	Three conditions: visual only (V) vs. auditory only (A) vs. audiovisual (AV, always congruent presentation)	Noise condition: ambient vs. broadband
Speech Intelligibility			
Level	70-80 dB	75 dB	Ambient: 38dBA (computer- and air conditioning background noise); broadband: additional 75dBA continuous wideband noise
Performance	Frankfurter Attention Inventory Test	Visual detection task of presented target category (drawing of dog or car) on the attended location using a 1-back approach	Decision making task: Water Purification Plant (WPP) task, performance averaged over three sessions/days
Task Load			Low: no task vs high: concurrently performing n-back task
Distraction		Task-irrelevant auditory stimulation (congruent sound to visual target/non-target)	
Perceived Disturbance	Perceptions of Background Music on -5 (interfering) to 5 (facilitating) scale		
Additional Information*	Perceived State of Arousal Scale, 5-point rating scale	57-channel EEG measured	Effect of gender as a moderator investigated

*Annoyance, Mood, Health, Job Satisfaction, Environmental Satisfaction, Moderator
**There was no information available in the basic studies for the „workplace“ category