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The psychology of mountaineering: A systematic review

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Abstract

Research on the psychology of mountaineering has received widespread attention over many decades. Therefore, to clarify scientific findings in the area, provide future research directions, and enable the development of applied recommendations to enhance performance and safety, the purpose of this systematic mixed studies review was to identify, appraise, and synthesise research on the psychology of mountaineering. After systematically searching 10 electronic databases and undertaking manual searches up to April 2020, 69 studies published over 54 years (1966-2020) were included in the review. Thematic synthesis was undertaken and generated 11 descriptive themes, which were captured by two analytical themes, (i) personality characteristics of mountaineers, and (ii) psychological experiences in mountaineering. The synthesis generated novel insights into connections between different research topics in the psychology-specific literature in mountaineering, thus providing a more advanced understanding of current knowledge in this area. The review highlights that considerable progress has been made in this field, but further high-quality studies are required across all facets of this literature. Future avenues for research include: group dynamics; cognitive mechanisms underlying decision-making; and coping with setbacks and traumatic events.

Keywords: high altitude; climbing; sport psychology; adventure recreation; extreme environment.

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The psychology of mountaineering: A systematic review

Mountaineering involves ascending the rocky, icy, or snowy slopes of a mountain to reach its summit (Hartemann & Hauptman, 2005). Whilst some mountains can be summited by hiking or trekking, mountaineers climb mountains by routes that generally require technical equipment, such as crampons, ropes, and ice axes. Interest in mountaineering has proliferated since the 1950's, when Sir Edmund Hilary and Tenzing Norguays completed the first successful ascent of the world's highest peak, Mount Everest, in 1953, three years after Maurice Herzog and Louis Lachenal became the first climbers to summit an 8,000m mountain. Since these pioneering achievements, over 5,000 individuals have conquered the summit of Mount Everest, while over 30,000 successful ascents have taken place on the 14 'eight-thousander' peaks of the world (Himalayan Database, 2020). Additionally, membership figures from the International Mountaineering and Climbing Federation (2018) indicate the global reach of mountaineering, with over three million members registered across six continents. Furthermore, this figure is also likely to greatly underestimate mountaineering participation rates (Apollo, 2017).

Stories and images of triumphant summiteers on top of the world's highest peaks have captivated the public's imagination for over half a century, but statistical evidence on accident and mortality rates indicate that mountaineering is highly risky and fraught with danger (Wickens et al., 2015). Mountaineers climbing at extreme altitudes place themselves in some of the most treacherous environments on earth and can be exposed to perilous, life-threatening situations, such as avalanches, rock fall, and extreme weather conditions. With the inherent risk and potential for life-and-death situations in such environments, psychological factors are not only crucial for climbing success, but are paramount for keeping mountaineers alive (Burke et al., 2010).

Given the complex demands of mountaineering and the importance of psychological factors for performance and preserving life, the psychology of mountaineering has attracted considerable scholarly interest for over half a century. In light of the breakthroughs that occurred on Mount Everest in the 1950's, it is no surprise that much of the early scholarly work focused on Mount Everest expeditions, including the 1963 American Mount Everest Expedition team (Emerson, 1966; Lester, 1983), which completed only the third successful ascent of the mountain. Since then, literature on the psychology of mountaineering has continued to expand, with research conducted on specific expeditions over several continents (e.g., Cavaletti & Tredici, 1993; Kramer et al., 1993; Wagstaff & Weston, 2014) and across expertise levels, ranging from elite mountaineers who have summited 8,000m mountains multiple times (e.g., Crust et al., 2019) to less experienced, amateur participants (e.g., Burke et al., 2008).

Whilst considerable progress has been made in the evidence base, systematically reviewing the current state of empirical knowledge on the psychology of mountaineering would make an important contribution for several reasons. First, systematic reviews help to clarify what is known in an evidence base (Tod, 2019) and draw conclusions from multiple studies, thus providing a more comprehensive overview of knowledge than individual studies (Gough et al., 2017). As such, a review of this nature could generate a stronger and more complete picture of empirical knowledge on psychology in mountaineering. Second, by synthesising and clarifying scientific findings in the area, this could enable the development of recommendations for mountaineers, expedition teams, and practitioners to enhance performance and safety. Finally, given that systematic reviews are valuable for identifying research gaps and aid future research planning (Gurevitch et al., 2018), a systematic review could highlight directions for further research in this area.

Therefore, the aim of this study was to systematically review research on the psychology of mountaineering. Specifically, the objectives were to: (i) systematically search and appraise qualitative, quantitative, and mixed method research on psychology in mountaineering, and (ii) synthesise what is currently known about the psychology-specific literature in mountaineering. Consequently, the following research question was formulated: *What does published research evidence contribute to empirical knowledge of psychology in mountaineering?* By adopting an inductive approach and using thematic synthesis (Thomas & Harden, 2008) to address this research question, the review sought to advance understanding by developing a framework of knowledge that went beyond current evidence in individual studies on psychology in mountaineering.

Method

Design and Protocol

This systematic mixed studies review adopted a data-based convergent synthesis design (Hong et al., 2017) and followed guidelines for: preferred reporting items for systematic reviews and meta-analyses (PRISMA; see Supplemental data 1; Moher et al., 2009); synthesis without meta-analysis (SWiM; see Supplemental data 2; Campbell et al., 2020); and enhancing transparency in reporting the synthesis of qualitative research (ENTREQ; see Supplemental data 3; Tong et al., 2012).

Eligibility Criteria

Eligibility criteria were established to ensure that literature relevant to the review objectives was included (Tod, 2019). Studies were included if they: (i) were conducted with samples comprised of mountaineers; (ii) measured at least one psychological factor; and (iii) were original, full-length, peer-reviewed journal articles in the English language. In this review, we defined mountaineers as individuals who climbed mountains via routes that

require technical climbing. Participants referred to as mountaineers, mountain climbers, alpinists, and mountain guides were included. Only published studies were included as evidence indicates that grey literature can be of lower quality (e.g., Martin et al., 2005) and generally has a limited impact on review findings (e.g., Schmucker et al., 2017). Exclusion criteria were that: (i) activities consisted of trekking, simulated climbs, or other climbing variants, or (ii) studies were focused on mountaineering tourism or medical issues (e.g., effects of medication). Mountaineering tourism studies were excluded as the experiences of mountaineering tourists differ from those of individuals who engage in mountaineering as adventure recreation (Houge Mackenzie & Kerr, 2012). Studies involving multiple activities were excluded if data on mountaineers were not presented separately.

Information Sources and Search Strategy

An online search was conducted to identify relevant studies using 10 electronic databases: Academic Search Complete; CINAHL Complete; MEDLINE; APA PsycARTICLES; APA PsycINFO; PubMed; Scopus; SOC Index with Full Text; SPORTSDiscus with Full Text; and Web of Science (Core Collection). Databases were searched five times (March 2019-April 2020), with the final search conducted on April 23rd 2020. After scoping searches by the first author and subsequent discussions between the first and fifth authors, the search string consisted of the following search terms: [(Mountaineer*) OR (Mount* AND Climb*) OR (Mt. AND Climb*) OR (Expedition* AND Climb*) OR ("high altitude" AND Climb*) OR (“high-altitude” AND Climb*) OR ("High altitude" AND Expedition*) OR ("High-altitude" AND Expedition*)] AND (TX Psycholog*). The search string was modified to each database’s specifications and, where possible, results limited to peer-reviewed journal articles in the English language. The first search string block was searched in the title, abstract, and keyword fields, while the second block was searched in the full text field (see Supplemental

data 4 for full search strings). All retrieved articles were exported to Endnote X9 reference management software. Duplicates were identified using the automatic de-duplication feature and through manual screening.

Screening Process

Screening of the identified articles was undertaken at each stage by two authors independently. Titles and abstracts were checked for eligibility by the first and second authors. After this process, a meeting took place to discuss the outcomes and resolve any differences. Upon finalising studies that satisfied the eligibility criteria at the title and abstract stage, the full texts were checked for eligibility by the first and fifth authors. For studies with insufficient details to assess eligibility, further information was sought from the corresponding author. Both authors met to discuss the results of the full text screening process, resolve discrepancies, and agree reasons for excluding studies. Manual searches were undertaken by checking reference lists and forward citations (Google Scholar) of included studies, and other reviews that featured mountaineering (Boudreau et al., 2020; McEwan et al., 2019; Wickens et al., 2015). An almost perfect level of agreement was observed at the title and abstract ($\kappa = .87$) and full text ($\kappa = .91$) screening stages. Throughout the screening process, the third author, an experienced mountaineer and member of the prestigious Mount Everest summit club, was consulted to ensure that included studies met the eligibility criteria.

Data Extraction

A cross-tabulated form was developed to extract contextual information from the included studies. The following information was extracted for each study by the first and second authors independently: author(s); publication year; sample characteristics; data collection method; duration of data collection; analysis method; and highest altitude

reached by participants before or during the study. Comparison of data extraction forms indicated almost perfect agreement (κ = .90), with most differences arising due to inadequate reporting. All discrepancies were checked by both authors and consensual agreement on all contextual information was reached.

Data Synthesis

Data-based convergent synthesis designs analyse all data using a single method and this approach was selected as it is recommended for reviews that aim to identify main themes about a topic (Hong et al., 2017). Findings from the included studies were analysed in three stages following guidelines for thematic synthesis (Thomas & Harden, 2008). To facilitate this process, all included papers were imported into NVivo 12. Initially, the first author read each study twice to increase familiarity with the data prior to undertaking line-by-line coding of all data (author interpretations, participant quotes, and statistical data) in the results or findings sections. Coding was undertaken inductively without an *a priori* framework to ensure that new knowledge could be generated (Thomas & Harden, 2008). Consistent with guidelines for convergent synthesis designs (Pluye & Hong, 2014), quantitative data were transformed into codes through the process of 'qualitising' (Pope et al., 2007). By doing so, this enabled the integration of codes from all included quantitative, qualitative, and mixed method studies (e.g., the code *psychoticism* captured quantitative findings on this concept). Additional analysis was undertaken to synthesise the qualitised quantitative data further (see *Additional quantitative synthesis*). After the completion of coding by the first author, the second author read the relevant data and examined codes identified in 20% (k = 14) of included studies prior to a critical discussion between both authors. The aim of this process was not to achieve consensus or 'reliable' coding (Braun &

Clarke, 2019), but to encourage the first author to reflect on the coded data and challenge their interpretations in line with the critical friends process (Smith & McGannon, 2018).

In the second step, codes were compared and similar codes grouped together by the first author to generate descriptive themes, which involved the key step of translating concepts from one study to another (Thomas & Harden, 2008). Throughout this process, the first author also identified data that indicated connections between codes and descriptive themes. Codes were only included in the final review if they were found in at least two studies. After the initial development of descriptive themes by the first author, a critical peer debrief was conducted between all authors to facilitate collaborative reflexivity (Braun & Clarke, 2019). The first author discussed the codes and descriptive themes with the remaining authors, who acted as critical friends by appraising the analysis and offering alternative interpretations.

After agreeing on codes and descriptive themes, analytical themes were produced by interpreting the relationships and meanings across the descriptive themes. In doing so, this final step sought to ‘go beyond' findings reported in the original studies by generating new interpretations of the review topic (Thomas & Harden, 2008). To aid this process, the first author examined connections between the codes and descriptive themes, prior to producing an overarching framework depicting current understanding of the psychology of mountaineering and presenting this to the other authors for critical discussion.

After completing the synthesis, a sensitivity analysis was conducted to determine the relative contribution of included studies to the synthesis and assess the impact of study quality (SQ) on the findings (Thomas & Harden, 2008). The impact of SQ was determined by examining the effect of removing the bottom one-third of studies based on SQ scores on the synthesis.

Additional quantitative synthesis. To enable further analysis, interpretation, and synthesis of the qualitised quantitative data, standardised effect sizes (Cohen's *d*) were calculated, where possible, using Comprehensive Meta-Analysis (Borenstein et al., 2015). Effect sizes were calculated based on means, standard deviations, and sample sizes, or from other available statistics (e.g., *F*-statistic). Where data were presented in figures only and could not be retrieved, WebPlotDigitizer (Rohatgi, 2019) was used. All data were extracted by the first author and checked by the second author prior to computing effect sizes. Although many quantitative studies examined similar outcomes, a meta-analysis was not conducted due to the heterogeneity of: study designs; measures employed; and moderating variables (e.g., differences in altitude). Therefore, a narrative synthesis approach was adopted following guidelines (Campbell et al., 2020; Popay et al., 2006). Similar to previous research (e.g., Gunnell et al., 2019), quantitative outcomes examined in two or more studies were synthesised into categories (see below). Vote counting has been criticised for equally weighting effects from studies regardless of sample size (Gunnell et al., 2020), but a pragmatic approach was adopted in the current review given that most comparisons featured similar sample sizes. Additionally, we sought to overcome further limitations by: giving precedence, where possible, to standardised effect sizes over significance tests for categorisations rather than relying on underpowered analyses in the original studies; highlighting potential concerns with vote counting results within the narrative; and conducting a sensitivity analysis.

To categorise the quantitative outcomes, effect sizes ($-0.20 \geq d \geq 0.20$ = effect; $-0.19 \leq d \leq 0.19$ = no effect) and/or significance values ($p < .05$ = significant, $p \geq .05$ = non-significant) were used as criteria. The effect size range was selected on the basis that a

Cohen's *d* value of ≥ 0.20 can be interpreted as a small effect[1] (Cohen, 1988). Data for outcomes assessed in at least two studies were classified into one of three categories using the aforementioned criteria (*d* and/or *p*), with the category labels adapted appropriately for each outcome variable to aid interpretation. For cross-sectional data, findings were categorised as: *higher* (criteria indicated higher scores); *negligible* (criteria indicated negligible differences); or *lower* (criteria indicated lower scores). With the exception of one descriptive theme, all longitudinal data were categorised as: *increased* (criteria indicated higher scores); *negligible* (criteria indicated negligible differences); or *decreased* (criteria indicated lower scores). To aid interpretation, findings from neuropsychological tests were categorised as: *improvement* (criteria indicated improvement); *negligible* (criteria indicated negligible differences); or *deterioration* (criteria indicated deterioration). A study could feature in multiple categories in a code if more than one relevant outcome measure was obtained.

Quality Appraisal

Study quality was appraised using the 16-item quality assessment tool (QATSDD; Sirriyeh et al., 2012). The QATSDD contains criteria for assessing quantitative, qualitative, and mixed method studies on a 4-point scale, ranging from 0 (*not at all*) to 3 (*complete*). All studies were assessed with respect to criteria relevant to the study design with the exception of criterion 14, which was excluded due to criticism of reliability strategies in qualitative research (Smith & McGannon, 2018). Quality scores for each article were computed into a percentage. The quality of each study was appraised by two authors using a team approach, which involved the first, third, fourth, and fifth authors. Each of these

[1] According to Cohen (1988), the magnitude of the effect size *d* can be interpreted as: negligible ($d \leq 0.19$); small ($0.20 \leq d \leq 0.49$); medium ($0.20 \leq d \leq 0.49$); or large ($d \geq 0.80$).

authors assessed half of the included studies, with approximately one-third of each authors' allocation assessed by each of the other three authors. Studies that involved the third, fourth, and/or fifth authors were assessed by members of the team who were not authors in those studies. A moderate level of agreement was indicated by the interrater reliability coefficient (κ = .57). All discrepancies were resolved through discussions between the respective assessors.

Results

A total of 2,045 records were generated through the electronic database search, while a further 16 articles were identified through manual searches. Figure 1 indicates the number of studies: identified through database and manual searches; excluded at each stage of the screening process; and included in the review. Overall, 69 studies from 67 articles and 67 independent samples[2] were included. Three studies conducted by Barlow et al. (2013) were separated. Two studies (Bassi & Delle Fave, 2010; Delle Fave et al., 2003) were classified as one sample as data were for the same participants on the same expedition. Likewise, samples in two studies that involved the same participants (Brugger et al., 1999; Regard et al., 1989) were classified as an independent sample. The most common reason for exclusion (78.57%; *k* = 66) was that participants did not meet our definition of mountaineers, while data in five included articles were also omitted due to ineligibility (see Supplemental data 5 for exclusion reasons). The first results section provides an overview of the study designs, sample characteristics, and SQ. This is followed by the reporting of the thematic synthesis, which presents findings from the review in terms of analytical and

[2] Two studies sampled participants on the same expedition (Emerson, 1966; Lester, 1983), but no information was provided on sampling overlaps.

descriptive themes. Information on the sensitivity analysis constitutes the final results section.

[INSERT FIGURE 1 HERE]

Study Characteristics

Study design. The majority of included studies were quantitative (79.71%; *k* = 55), with the remainder using qualitative (*k* = 8) or mixed methods (*k* = 6). Thirty-eight studies collected cross-sectional data, while data in longitudinal (*k* = 30)studies were collected for: less than 30 days (*k* = 11); 30-90 days (*k* = 9); and more than 90 days (*k* = 7). The duration of data collection was not reported in three longitudinal studies or in the single prospective study in the review. Questionnaires (*k* = 42), neuropsychological tests (*k* = 19), and interviews (*k* = 13) were the most commonly used data collection methods.

Sample characteristics. A total of 4,983[3] mountaineers (male *n* = 4,128; female *n* = 766; gender not reported *n* = 89) participated in the included studies. Forty-one studies explicitly stated the highest altitude participants reached prior to or during the research. Based on altitude classifications (Wilson et al., 2009), most studies (*k* = 35) included participants who climbed or had previously climbed at extreme altitude (> 5,500m), while the remainder climbed at very high altitude (3,500-5,500m - *k* = 6). In terms of extreme altitude experience, 22 studies sampled participants who reached above 8,000m, which is commonly referred to as the 'death zone'.

[INSERT TABLE 1 HERE]

Study quality. Results of the SQ check are presented in Table 2. The highest SQ scores were recorded for qualitative (*M* = 69.87%), followed by quantitative (*M* = 44.56%)

[3] Crust et al. (2019) sampled 11 participants from a previous study (Crust et al., 2016). Thus, only unique participants (*n* = 6) were included in the total figure.

and mixed method studies (*M* = 37.78%). The most common issues were that studies did not: justify their sample size; provide information on reliability and validity; involve users in the study design; and critically discuss strengths and limitations. Although the quality of a substantial proportion of included studies could raise some questions about their inclusion, no study was excluded based on quality as all studies were deemed relevant and could contribute to the overall understanding of psychology in mountaineering. Instead, a sensitivity analysis was undertaken to examine the impact of SQ on the synthesis.

[INSERT TABLE 2 HERE]

Thematic Synthesis

The synthesis generated two analytical themes: (i) personality characteristics in mountaineering, and (ii) psychological experiences in mountaineering. These two analytical themes stemmed from 43 *codes* captured by 11 descriptive themes, which are presented in the following sections. Supporting data for quantitative categorisations and synthesis of qualitative data are presented in tables, while participant quotes are included to facilitate the voice of participants (see Supplemental data 6 and 7 for further supporting information). This section concludes with an overview of connections identified in the synthesis, some of which are discussed within the descriptive themes.

Personality characteristics in mountaineering. The first analytical theme reflected understanding of the personality of mountaineers (Table 3) and encompassed four descriptive themes: big five personality traits; mental toughness; risk-taking; and social aspects of personality.

[INSERT TABLE 3 HERE]

***Big five personality traits*.** This descriptive theme synthesised cross-sectional comparisons between relatively small samples of mountaineers (*n* range = 7-90) and non-

athlete samples on the big five personality traits. Only 37.5% of studies synthesised in this code (k = 8), however, used measures based on the five-factor model (Barlow et al., 2013[study 3]; Savage et al., 2020; Smith, Kinnafick et al., 2017). While findings were not always consistent, the synthesis suggested that mountaineers differed on several traits. Specifically, multiple studies found mountaineers reported lower *neuroticism* (k = 5/7), and higher: *conscientiousness* (k = 2/3); *extraversion* (k = 4/7); and *openness to experience* (k = 2/3). Conversely, assessments of *agreeableness* were equivocal (k = 1/3 for each category), but only indicated small differences ($-0.27 \leq d \leq 0.30$).

Mental toughness. Understanding of mental toughness (MT) was drawn from interview studies (k = 4) with elite mountaineers. A myriad of *characteristics of MT* were evident, with the ability to endure the discomfort synonymous with extreme altitude mountaineering emerging as a salient feature. Mentally tough mountaineers were also characterised by calmness and rationality in crisis situations: 'People that are mentally tough can take all the ups and downs with more calm because I think we act in a more rational way' (Swann et al., 2016, p. 163). These qualitative studies also revealed *benefits and drawbacks of MT*. For example, MT was considered vital for summiting Mount Everest (Burke & Orlick, 2003) and facilitated more adaptive coping responses in the immediate aftermath of the 2015 earthquake on the mountain (Swann et al., 2016). Additionally, MT was deemed crucial when mountaineers needed to decide on whether to persevere or turn around without summiting, which was often considered the more difficult decision. That said, while MT was generally associated with pragmatic perseverance, it was not always beneficial, and could, in some cases, endanger mountaineers: 'I think the main drawback is not being able to know when to give up. To keep pushing as far as you can and then being past the point of no return' (Crust et al., 2016, p. 605).

***Risk-taking*.** Codes concerning personality characteristics related to risk-taking could be broadly stratified into two categories. The first category mainly encompassed quantitative, cross-sectional studies that compared mountaineers to non-mountaineers on risk-related personality traits. The most commonly researched trait was *sensation-seeking* (*k* = 11). Multiple cross-sectional studies indicated that small samples of mountaineers (*n* = 7-39) reported higher *sensation-seeking* compared to controls or low-risk sport groups (*k* = 6/6). Compared to other high-risk sports, however, findings were more inconsistent, with scores in mountaineers classified as: higher (*k* = 3/5); negligible (*k* = 3/5); and lower (*k* = 1/5). The synthesis also identified some evidence of higher *psychoticism* (*k* = 2/3), and similar or lower *impulsiveness* (both *k* = 2/3) in mountaineers versus low-risk controls. Findings in these codes, however, should be viewed with caution due to the small sample sizes (*n* ≤ 58) and potential impact of SQ (See Sensitivity analysis). The remaining codes cohered around mountaineers' perceptions of risk-taking synthesised primarily from qualitative studies. In terms of *risk-taking attitudes,* elite mountaineers felt that the activity would be considered riskier by people outside the mountaineering community, but simultaneously outlined their awareness of the dangers involved and the extensive measures taken to mitigate risk and improve safety (Crust et al., 2016). Additionally, there was evidence of the *importance of experience* for risk-taking. Experienced mountaineers described changes in *risk-taking attitudes* over time, whereby they practiced more safely as a result of gaining experience (Davidson, 2012).

***Social aspects of personality*.** This descriptive theme centred on the behaviours of mountaineers in *managing relationships and social interactions*. A characteristic of mountaineers drawn from several small samples was a tendency for withdrawal or disinterest in social situations (Lester, 1983; Noël-Jurand et al., 2001). Findings from higher-

quality qualitative studies, however, suggested that withdrawal was a necessary coping response when mountaineers needed to find 'psychological space' in stressful and mentally demanding situations: 'Sometimes you just have to get away from it. Everybody needs time out' (Wagstaff & Weston, 2014, p. 284).

Psychological experiences in mountaineering. The second analytical theme comprised the psychological experiences of participants in mountaineering (Table 4), and captured seven descriptive themes: affective phenomena; cognitive phenomena; metacognitive experiences; mental health; neuropsychological functioning; regulatory processes; and group processes.

[INSERT TABLE 4 HERE]

***Affective phenomena*.** This descriptive theme captured quantitative and qualitative insights related to affect, mood, and emotion. Happiness was a consistently reported *positive affective response* (e.g., 41% of self-reports during a 2-month expedition; Wagstaff & Weston, 2014), with feelings of happiness and enjoyment derived from the extreme challenges and adventure involved in mountaineering (Pereira, 2005). The unique stressors experienced in mountaineering also produced *negative affective responses.* For example, one participant outlined the intense fear during an earthquake on Mount Everest: 'All of us thought we were gone, without a doubt…A most sickening feeling of fear I have ever, ever had' (Swann et al., 2016, p. 161). Furthermore, physical and environmental stressors negatively affected mood in small expeditions (n = 6-9). Unsurprisingly, significantly decreased vigour and increased fatigue were reported after the most physically demanding periods at higher altitudes (d = -0.81 and d = 1.06-1.66, respectively - Karinen & Tuomisto, 2017; Shukitt-Hale et al., 1990), while a moderate decrease in mood occurred during a weather emergency (d = -0.75 - Bassi & Delle Fave, 2010).

***Cognitive phenomena*.** The synthesis generated insights into perceived cognitive phenomena in mountaineering from quantitative and qualitative data. Intrinsic motives were important sources of *motivation* for all mountaineers. Elite mountaineers were strongly motivated by the opportunity to challenge themselves and test their skills (Burke et al., 2010), while large-scale, quantitative studies identified the physical setting as the most strongly endorsed motive (Burns et al., 2020; Ewart, 1985). During *decision-making,* elite mountaineers explained that decisions needed to be guided by rational and logical thinking rather than emotions, as impulsive, emotionally-driven decisions could be catastrophic (Crust et al., 2016). When making such decisions or when faced with crisis situations that reduced perceptions of control, the importance of exerting and regaining a sense of *agency* was articulated (Crust et al., 2019; Swann et al., 2016). Indeed, cross-sectional, quantitative evidence indicated that mountaineers reported moderately higher *agency* while participating compared to low-risk controls (Barlow et al., 2013 [study 2 d = 0.73; study 4 d = 0.76]), thus suggesting that this could be a key experiential component of the activity. The synthesis also revealed factors associated with changes in *confidence*. Elite mountaineers sourced *confidence* from preparation, reaching goals, and past experiences (Burke & Orlick, 2003). Conversely, Bassi and Delle Fave (2010) found that a setback in the form of a weather emergency produced a large *confidence* decrease (d = -1.22) in a small expedition team (n = 6). Variations were also evident in the *quality of experience* on that expedition, as optimal experience was reported most frequently during climbing and camp activities, but relaxation and apathy were synonymous with leisure and maintenance activities, respectively (Delle Fave & Bassi, 2003). After expeditions, there was widespread evidence that mountaineering had a positive *impact on self-perceptions*. Cross-sectional, quantitative evidence, for example, indicated small-to-moderate growth after expeditions (Smith, Kinnafick et al.,

2017), with one elite mountaineer explaining the wide-ranging impact of summiting Mount Everest: 'I have the confidence to tackle new challenges; challenges that are outside of my expertise which have led to further diversification, liberation, satisfaction, and balance in my life' (Burke & Orlick, 2003, p. 52).

***Metacognitive experiences*.** While the term metacognition did not feature in any qualitative findings, synthesised participant quotes produced insights into metacognitive processes. Mountaineers generated *metacognitive feelings* through the assimilation of internal and external stimuli (see Regulatory processes). Elite mountaineers reported a feeling of difficulty when experiencing exertional discomfort and fatigue, and a feeling of knowing 'exactly what is going on inside my body when I feel a particular physical sensation' (Burke et al., 2010, p. 389). Such *metacognitive feelings* often led to *metacognitive judgements and estimates*, which informed decisions. For example, one mountaineer reported judgements about their progress and physical state, and estimates of risk prior to turning around on K2:

> I'm like the avalanche danger is high; the chance of serac collapse is high; we're not moving fast enough; we're not gonna be able to get through the Bottleneck before it's dark, and then I also wasn't feeling 100%. (Crust et al., 2016, p. 604)

While using such information could improve decision-making, overruling or failing to make accurate *metacognitive judgement and estimates* endangered mountaineers (Crust et al., 2016) and caused injuries (Pereira, 2005). Importantly, the ability to understand ones mental processes was enhanced by acquiring *metacognitive knowledge*. That is, gaining experience enhanced the ability of mountaineers to acquire insight into different stimuli: 'The biggest challenge was discerning the harmless pain from the warning bells. What is

danger pain and what is just plain discomfort? More experience led to more confidence in my ability to judge' (Burke & Orlick, 2003, p. 52).

***Mental health*.** This descriptive theme encompassed understanding of mental health in mountaineering, and primarily consisted of longitudinal studies that examined changes in mental health during and after (timeframe post-expedition range = 4-75 days) expeditions. Mountaineering appeared to have a long-term regulatory effect on state *anxiety*, as decreases were consistently found from pre-to-post expedition (*k* = 5/5). Findings concerning changes during mountaineering were more inconsistent, but evidence from higher quality studies, albeit in relatively small samples (*n* = 7-9), indicated decreases in *anxiety* at higher altitudes (*k* = 4/6). Conversely, increases in *depression* at later stages in expeditions were found more frequently (*k* = 3/5) than negligible changes or decreases (*k*'s = 2/5 and 1/5), while large increases were also reported in *obsessive compulsive disorder* (*k* = 2/2) and *paranoia* (*k* = 2/2). Findings concerning *obsessive compulsive disorder* and *paranoia*, however, should be interpreted with caution (see Sensitivity analysis). Collectively, evidence from longitudinal studies on changes in overall mental health during expeditions appeared somewhat equivocal, but offer tentative evidence that some mental health symptoms might be more adversely affected during expeditions than others. The final code, *post-traumatic stress disorder* (PTSD), was mainly synthesised from cross-sectional studies in mountain guides, who reported low levels of PTSD (Harkensee & Hillebrandt, 2019; Sommer et al., 2004).

***Neuropsychological functioning*.** This descriptive theme synthesised data on the effects of very high and extreme altitude exposure on neuropsychological functioning (NF). Although some NF tests assessed multiple outcomes, all tests were categorised into a single code in the current review to avoid overlaps (see Supplemental data 7). With the exception

of a single study (Regard et al., 1989), NF was studied longitudinally (*k* = 17). Amongst studies that measured NF repeatedly during expeditions (*k* = 13), just over half (53.84%; *k* = 7) assessed participants after extreme altitude exposure, although the highest point for testing in most studies was very high altitude (76.92%; *k* = 10), with only three studies obtaining data at extreme altitudes. While findings were not always consistent within and between studies, improvements or negligible changes were evident more often than deteriorations in: *complex attention* (*k* = 3/8 and *k* = 3/8 versus *k* = 4/8); *executive functions* (*k* = 3/6 and *k* = 5/6 versus *k* = 1/6); *memory and learning* (*k* = 6/9 and *k* = 6/9 versus *k* = 1/9); and *perceptual and motor functioning* (*k* = 1/7 and *k* = 4/7 versus *k* = 3/7). The effects on *language*, however, revealed equivocal findings. While fluency was unaffected at higher altitudes (Merz et al., 2013; Lieberman et al., 1995), large deteriorations were found in syntax (*d* = 2.00-2.66 - Lieberman et al., 1995) and expressive language ability (*d* = -0.86 - Petiet et al., 1988). Furthermore, although some *motor and perceptual functions* appeared unaffected, significant deteriorations were found in perception (*d* = -2.03 - Machado & Andrade, 1985; *d* = 1.09-1.33 - Nelson, 1982) and speech motor control (*d* = -2.26 - Lieberman et al., 1995), thus suggesting a need to view findings more critically. Importantly, there was evidence that deteriorations in NF could begin to reverse after mountaineers descended to lower altitudes (Lieberman et al., 1995). Likewise, acclimatisation was identified as a key mechanism for guarding against the adverse effects of altitude on NF. For instance, Pagani et al. (1998) found a large, significant improvement in learning after more than two weeks of acclimatisation at very high and extreme altitude compared to pre-acclimatisation. Studies that examined the impact on NF after expeditions (*k* = 12; timeframe post-expedition range = 4-221 days) found more consistent trends. Specifically, improvements or negligible changes were found more frequently than deteriorations in:

complex attention (*k* = 4/8 and 6/8 versus *k* = 2/8); *executive functions* (*k* = 3/5 and *k* = 4/5 versus *k* = 1/5); *memory and learning* (*k* = 4/10 and *k* = 7/10 versus *k* = 4/10); *language* (*k* = 3/4 and *k* = 3/4 versus *k* = 1/4); and *perceptual and motor functioning* (*k* = 2/6 and *k* = 6/6 versus *k* = 1/6). Overall, the synthesis suggests that very high and extreme altitude exposure produces some acute deteriorations in NF, but offers less evidence of a long-term deterioration. This perspective, however, should be interpreted with caution as: sample sizes ranged from 3-32, with 70.59% (*k* = 12) of longitudinal studies sampling 3-12 mountaineers; some authors attributed improvements and null findings to practice effects (Machado & Andrade, 1985; Petiet et al., 1988); only two studies included control groups (Clark et al., 1983; Kramer et al., 1993); and the impact of very high and/or extreme altitude exposure was only examined across single rather than repeated expeditions.

***Regulatory processes*.** Primarily drawn from qualitative studies, this descriptive theme comprised strategies used to regulate cognition, emotions, and behaviours. Engaging in extensive *planning before mountaineering* was crucial for increasing the likelihood of expedition success and improving safety. Preparation for expeditions included anticipatory planning of challenges and responses: 'I like to sit down and consider all the possible outcomes that could arise over the length of an expedition and develop strategies to cope and accept them' (Burke et al., 2010, p. 386). During mountaineering, participants engaged in *attentional monitoring* of external and internal stimuli. Outward monitoring involved focusing on environmental conditions (e.g., 'the weather became truly bad. I decided to come down.' Pereira, 2005, p. 42), while internally monitored sensations often centred on exertional discomfort and physical warning signs (e.g., signs of frostbite - Crust et al., 2016). When undesirable cognition and emotions were experienced, mountaineers sought to manage these by using *self-regulation strategies*. Suppression was a widely reported

emotion regulation (ER) strategy used to facilitate rational thinking (Crust et al., 2016). Despite its perceived effectiveness, emotional suppression could come at a cost, as it was positively related to mental fatigue (*d* = .65 - Wagstaff & Weston, 2014) and was cited as an antecedent of long-term emotional difficulties (Swann et al., 2016). Additionally, goal-setting was used to regulate cognition and behaviour. Elite mountaineers articulated the importance of setting short-term, process goals (Burke & Orlick, 2003) and being prepared to adapt or abandon goals when continued goal pursuit was unsafe or when other tasks, such as rescue attempts, were more important (Swann et al., 2016). Additionally, *distractive strategies* were used to purposefully direct attention *away* from undesirable cognition and emotions, but were typically reported during non-mountaineering activities. For example, experienced mountaineers regulated their emotions by listening to music and reading when resting in camp areas (Wagstaff & Weston, 2014).

Group processes. This descriptive theme captured psychological elements surrounding group processes. The synthesis revealed a range of negative interpersonal outcomes during expeditions. When mountaineers struggled to suppress negative emotions, this often led to *conflict,* which could have an adverse psychological impact: 'I was in conflict with people and it did detract from my ability to focus on other things because I was worrying about conflict with one individual' (Wagstaff & Weston, 2014, p. 283). Quantitative studies in relatively small samples (*n* = 20-31) also found increases in *hostility* and *interpersonal sensitivity* at later stages in very high altitude climbs (Coksevim et al., 2007; Nelson, 1982), although these findings should be taken with caution (see Sensitivity analysis). While negative aspects of group processes were highlighted, the importance of group dynamics for performance, safety, and psychological outcomes was evident. A critical process for success and survival was *social support.* Indeed, choosing a trusted climbing

partner was deemed vital for reducing risk when faced with challenges (Crust et al., 2019). Furthermore, *leadership* influenced interpersonal perceptions. For instance, members of a Mount Everest expedition team who experienced a democratic leadership style evaluated their leader more favourably versus those who experienced an autocratic style (Bratton et al., 1983).

Synthesis of Findings

A map depicting relationships generated through the synthesis at analytical and descriptive theme levels is presented in Figure 2. Overall, this framework provides an overview of current understanding of the psychology of mountaineering. A total of 26 connections and two conceptual overlaps were identified between the descriptive themes (see Supplemental data 8 for explanations). Although the review primarily consisted of quantitative studies, the majority of understanding concerning the identified connections stemmed from higher-quality, qualitative studies, as the contribution of quantitative studies was often restricted to a single code or descriptive theme.

A key finding generated through the synthesis was the impact of personality on the psychological experiences of mountaineers. The personality characteristics of mental toughness and risk-taking were connected to several facets of the psychological experience in mountaineering, such as: affective phenomena; cognitive phenomena; metacognitive experiences; and regulatory processes. A noteworthy finding was that these connections were highly salient during decision-making and risk management processes. For example, mentally tough mountaineers were characterised by: *metacognitive feelings* of knowing when sensory information suggested their body was not coping; an analytical approach to *decision-making*; and a tendency to manage *negative affective responses* more effectively in crisis situations through the use of *self-regulation strategies during mountaineering*.

Likewise, *risk-taking attitudes* reported by experienced mountaineers were associated with: extensive *planning before mountaineering* to improve safety; a desire to avoid unnecessary danger, as reflected in their *decision-making*; and using *metacognitive knowledge* to reduce risk. Therefore, the synthesis offers important insights into the role of personality in the psychological experience of mountaineering, especially in terms of decision-making and safety.

Additionally, the range of unidirectional and bidirectional connections within the analytical theme, psychological experiences in mountaineering, highlighted the complex and multifaceted nature of mountaineers' experiences while participating. During climbs, for example, mountaineers explained how they used information generated through *attentional monitoring* (regulatory processes) to form *metacognitive feelings* and *metacognitive judgements and estimates* (metacognitive experiences). The outcomes of these processes were subsequently used to inform *decision-making* (cognitive phenomena) and, in some cases, identify appropriate *self-regulation strategies* that could be employed (regulatory processes). Alongside these cognitive processes, mountaineers utilised *self-regulation strategies during mountaineering* to manage *negative affective responses* (affective phenomena) and facilitate more rational *decision-making* (cognitive phenomena). Furthermore, the findings highlighted the interplay between cognitive, affective, and social features of the mountaineering experience; for instance, the ineffective use of *self-regulation strategies* (regulatory processes) in response to *negative affective responses* (affective phenomena) often led to interpersonal *conflict* (group processes). As such, these findings elucidate the intricacies and complexities of the psychological experience in mountaineering.

[INSERT FIGURE 2 ABOUT HERE]

Sensitivity Analysis

The sensitivity analysis (see Supplemental data 9) indicated that the majority of codes in the synthesis (91%) sourced data from three or more studies, with only four codes developed based on data from two studies. Four studies included in the review (Brugger et al., 1999; Burnik et al., 2002; Gürer, 2015; Missoum et al., 1992) did not feature in the synthesis as codes generated in these studies did not translate to any other study. Eighteen studies in the synthesis contributed to a single code, with the majority (k = 30) featured in 2-5 codes. The remaining studies (k = 17) were cited in at least six codes, with eight of these studies capturing interview data. The sensitivity analysis revealed that omitting the bottom one-third of studies based on SQ (k = 24) would have led to the removal of four codes: *hostility*; *interpersonal sensitivity; obsessive compulsive disorder;* and *paranoia*. Furthermore, findings concerning changes in *executive function* and *psychoticism* during expeditions would have been sourced from less than two studies, whilst differences in *psychoticism* and *impulsivity* between mountaineers and non-mountaineers would have been equivocal. Therefore, while these findings are included in the synthesis, the sensitivity analysis indicates possible quality concerns and suggests that caution should be taken when interpreting some findings.

Discussion

The current study constitutes the first systematic review of literature on the psychology of mountaineering. By comprehensively synthesising this evidence base, the review offers novel understanding of the personality characteristics of mountaineers and psychological experiences involved in mountaineering. Furthermore, the synthesised findings were organised into a framework (Figure 2) that provides a holistic overview of

more than five decades (1966-2020) of knowledge in the field. While some issues were identified with SQ, the findings make several important contributions.

The synthesis offers insights into the personality idiosyncrasies of mountaineers. In line with a previous meta-analysis of personality traits in high-risk sport groups (McEwan et al., 2019), sensation-seeking was consistently higher in mountaineers compared to low-risk sport athletes and non-athletes. Although such findings suggest that mountaineers are more likely to take risks, these findings are drawn solely from cross-sectional studies and no research has yet examined the relationship between sensation-seeking and risk-taking *behaviours* in mountaineers. Indeed, the synthesised qualitative findings indicated that reducing risk was imperative for experienced mountaineers, who undertook extensive measures to reduce risk. Some evidence, however, did indicate that less experienced (Davidson, 2012) and less mentally tough (Crust et al., 2019) mountaineers were more likely to take risks. Therefore, it is important for mountaineers, expedition leaders/organisers, and mountain guides to understand the potential influence of such individual differences on risk-taking.

Given the accident rates and potentially life-threatening consequences associated with mountaineering, understanding the mechanisms underlying decision-making is vital for improving safety. By integrating qualitative data across a range studies, this synthesis offers new information by illustrating the complex interplay of emotional, metacognitive, cognitive, and regulatory processes underlying decision-making in mountaineering. Crucially, the synthesised findings were based on higher-quality studies that involved elite or experienced mountaineers. Therefore, on the basis that these mountaineers were likely to have had a broader experiential reference base to draw upon when discussing decision-

making, the findings are an important source of knowledge for improving safety in elite mountaineers, and sub-elite mountaineers who aspire to reach higher levels.

While no included study employed a metacognitive perspective to investigate decision-making, the synthesis makes an innovative and valuable contribution to this literature by drawing on empirical data in included studies to elucidate metacognitive processes in mountaineering decision-making. To date, most research on attentional focus and metacognitive processes in athletes has focused on endurance running (Brick et al., 2014), but findings of the current synthesis suggest that applying a metacognitive framework to mountaineering could enhance understanding of decision-making in this context. For example, elite mountaineers explained that after processing internal and external stimuli, the decision to turn around without summiting was often preceded by metacognitive feelings of knowing, which would result in a metacognitive estimate of risk that led to the abandonment of a summit attempt. By creating deeper insights into the higher-order mental processes involved in mountaineering decision-making, this represents an important step forward in this literature. Furthermore, the synthesis indicated that developing metacognitive knowledge could improve the ability of participants to understand their cognition at a meta-level. Indeed, this finding is also noteworthy from a performance perspective as metacognitive processes are considered key for the development of expertise (MacIntyre et al., 2014). Thus, metacognition could be beneficial for developing expertise as well as safety in mountaineering. In turn, this suggests that developing interventions that seek to help mountaineers acquire greater insight into, and control over, their mental processes could act as a valuable adjunct to experiential learning for improving performance and safety.

Another critical factor that facilitated cognitive aspects of decision-making in crisis situations was effective ER, with emotional suppression widely reported in decision-making scenarios. Although athletes are generally advised to avoid suppressing unwanted thoughts (Uphill et al., 2009), there are several reasons why emotional suppression might be more common in mountaineering. Unlike most sports teams, mountaineers can spend long periods in close proximity to their team members in extreme and isolated environments, which could increase the need for suppression to maintain team relations (Wagstaff & Weston, 2014). Additionally, suppressing emotions might be preferred when mountaineers face life-threatening situations, as these emotions could be unhelpful for managing immediate tasks (e.g., disaster rescues - Swann et al., 2016). Finally, as males are more likely to use suppression than females (e.g., Gross & John, 2003), the gender bias in the review sample (82.84% males), which is reflective of mountaineering participation rates (Pomfret & Doran, 2015), could have contributed to the apparent pervasiveness of this strategy. Despite its widespread use and perceived effectiveness, suppression was associated with negative consequences (Swann et al., 2016; Wagstaff & Weston, 2014). Thus, mountaineers should avoid relying solely on suppression and should employ a variety of ER strategies, including cognitive strategies, to manage unpleasant emotions (Wagstaff & Weston, 2014). Furthermore, mountaineers should seek support to manage suppressed emotions, particularly following traumatic incidents.

Finally, the need to function with reduced oxygen is an axiomatic characteristic of mountaineering (Wickens et al., 2015). Consistent with previous reviews on environmental conditions and cognitive performance (Martin et al., 2019; Taylor et al., 2016), the synthesis identified evidence of deteriorations in NF at very high and extreme altitudes. Although more high-quality studies are needed to clarify equivocal evidence in this area, these

findings are noteworthy as cognitive impairment and ataxia are common symptoms of climbers who have died while mountaineering (Firth et al., 2008). In turn, the findings highlight the need to closely monitor mountaineers' responses at higher altitudes and emphasise the importance of taking measures to reduce the impact of hypoxia-related NF impairments.

Methodological Reflections and Implications for Future Research

This systematic review highlights several methodological issues that should be addressed in future research. First, studies were most commonly excluded because participants did not meet our definition of mountaineers. Given that mountaineering differs from other mountain or climbing activities, researchers should clearly describe their samples to strengthen the internal validity of findings. Second, while the review involved a large sample of 4953 mountaineers, 73.77% (*k* = 45) of studies that obtained quantitative data (including mixed methods) sampled less than 50 participants, with the remaining 16 studies involving 4069 participants. While we sought to overcome the potential for type II errors by calculating effect sizes, future studies should seek to recruit larger samples and examine statistical power. Third, inconsistent findings were identified in several descriptive themes, which could be attributed to the: heterogeneity of measures employed; differences in sample sizes; testing at different altitudes; and impact of moderating variables (e.g., route demands, acclimatisation duration, environmental factors) that were inconsistent, were/could not be delimited, or were not reported. While some moderating variables cannot be controlled by researchers, improved reporting would aid interpretation, evaluation, and cross-study synthesis of findings. Fourth, longitudinal studies that examined the effects of altitude on NF only assessed participants in a single expedition. Further research should examine the effects of repeated exposure to extreme altitudes. Finally, the

sensitivity analysis identified issues with SQ in several codes. Thus, further research is warranted to clarify findings in these areas.

Additionally, the synthesis highlighted a range of areas that could benefit from further development. First, little attention has been directed towards group dynamics, which is surprising given that group processes are an integral feature of expeditions and that poor group dynamics could have devastating consequences. Further research could, for example, examine intra-team relations (e.g., interpersonal ER), teamwork, and coping with setbacks. Second, by applying a metacognitive framework to data synthesised from qualitative studies, this review makes an innovative contribution to understanding of decision-making. Nonetheless, further empirical work that explicitly examines mechanisms underlying decision-making from a metacognitive perspective is warranted. Furthermore, such research should also investigate sub-elite mountaineers to enable comparisons with elite mountaineers. Third, personality researchers should move beyond cross-sectional designs and examine causal effects. For example, researchers could undertake prospective, quantitative examinations of connections between personality traits and other descriptive themes presented in Figure 2. Finally, whilst some research captured elements of coping, more targeted, longitudinal data collection could provide deeper insights into how mountaineers cope with the unique, life-threatening challenges faced. While these areas are highlighted as research avenues moving forward, all codes in the review could benefit from additional, high-quality studies that address more complex research questions and utilise more rigorous methods to provide greater clarity. In turn, this could have important implications by enabling the development of more robust, applied recommendations that improve mountaineering performance and safety.

Strengths and Limitations

As the first systematic review on the psychology of mountaineering, this review has several strengths. By using a strict definition of mountaineers, the results have strong internal validity. The review process was systematic, transparent, and utilised various strategies to improve trustworthiness (e.g., following reporting guidelines; critical friends; computation of standardised effects sizes; screening, data extraction, and SQ checks by multiple authors; sensitivity analysis). Furthermore, as the synthesis produced new conceptual understanding, the findings represent a form of analytical generalizability (Smith, 2018), while naturalistic generalization (Stake, 1995) could also be achieved if the findings resonate with other mountaineers. Despite these strengths, several limitations should be noted. The eligibility criteria led to the omission of potentially relevant data as some eligible participants were excluded due to not satisfying the inclusion criteria. Likewise, the review could be susceptible to language and publication bias as only full length, peer-reviewed articles in the English language were included. Research suggests, however, that non-English and unpublished studies can only represent a small proportion of relevant studies in a field and rarely have a substantial impact on reviews with a high number of relevant studies (e.g., Hartling et al., 2017). Finally, while vote counting was considered the most suitable approach for synthesising quantitative data, future research should use more complex meta-analytical approaches to examine different outcomes as more evidence accumulates.

Conclusion

This systematic review contributes original knowledge by synthesising over 50 years of empirical work on the psychology of mountaineering. The synthesis summarises what is known about the personality characteristics of mountaineers and provides insights into

psychological experiences in mountaineering. Furthermore, the use of thematic synthesis deepens understanding of the complex interactions between the personality characteristics of mountaineers and experiences that occur in the activity. Practically, the review highlights several recommendations for improving performance and safety in mountaineering, which could help mountaineers, expedition leaders, and mountain guides. Moving forward, researchers should use more robust research designs, including prospective and longitudinal approaches, to advance understanding.

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Table 1: Contextual information on included studies.

Study ID	Author	Sample characteristics (male/female) M_{age} or range	Data collection	Duration of data collection	Data analysis	Highest altitude reached before or during study
Quantitative						
A1	Anicich et al. (Study 1; 2015)	130 (116/14) 41.80	Questionnaire on processes contributing to performance and psychological responses to different group cultures on a hypothesised Himalayan expedition	Cross-sectional	*t*-test Mixed model ANOVA	> 8000m
A2	Aras et al. (2018)	7 (7/0) 40.14	SSS-V and STAI pre-expedition and before (6400m) summiting Peak Korzhenevskaya or Lenin Peak	Not reported	Paired sample *t*-test or Wilcoxon test	7105m
A3	Barlow et al. (Study 2; 2013)	28 (23/5) 38.04	SEAS	Cross-sectional	ANOVA ANCOVA	Not reported
A4	Barlow et al. (Study 3; 2013)	39 (35/4) 30.36	SEAS, SSS-V, EIS ability to regulate one's own emotions subscale, PMS lack of mastery subscale, TIPI, and BIDR	Cross-sectional	ANOVA ANCOVA	Not reported
B7	Barlow et al. (Study 4; 2013)	46 (37/9) 30.24	SEAS and ratings of expectancy of experience of ER and agency	Cross-sectional	ANOVA ANCOVA MANOVA Discriminant function analysis	Not reported
A6	Bassi and Delle Fave (2010)	6 (6/0) 29.30	ESM across a Thalay Sagar expedition	26 days	*t*-test	Not reported
A7	Bektaş (2013)	29 (22/7) 49.06	Attention test at BC (3200m) and a camp (4200m) before and after summiting Mount Ararat	4 days	Repeated measures ANOVA	5137m
A8	Breivik (1996)	45 (45/0) 30.72[1]	16PF, SSS-V, RT5, and OQ-II	Cross-sectional	ANOVA *t*-test Correlations	8848m
A9	Burnik et al. (2002)	40 (20/20) 22-30	FPI-114	Cross-sectional	*t*-test	Not reported
A10	Burnik et al. (2005)	58 (58/0) 31.54	FPI-114	Cross-sectional	*t*-test	Not reported
A11	Burnik et al. (2008)	33 (15/18) 24.93	SSS-IV	Cross-sectional	*t*-test	Not reported
A12	Burns et al. (2020)	865 (721/113)[3] < 30 to > 50	Questionnaire assessing motives for mountaineering on Mount Hood or Mount Baker	Cross-sectional	Frequency statistics *t*-test Linear regression analysis	Not reported
A13	Castanier et al. (2011)	105 (105/0) 29.07	FREI, PNEI negative affect subscale, and PNES before a mountain route, and the PNES after the route	Not reported	Correlation analysis ANCOVA Regression analysis	Not reported
A14	Cavaletti and Tredici (1993)	11 (11/0) 23-48	Attention, executive function, and memory tests before and after (+75 days) ascents of Pik Pobeda or Nevado Alpamayo	> 105 days	*t*-test	7439m

A15	Cavaletti et al. (1990)	10 (9/1) 18-32	Memory, language, and motor functioning tests, and self-ratings of anxiety and depression before and after (+75 days) a 7000m Himalayan climb	118 days	*t*-test	7000m
A16	Clark et al. (1983)	22 (17/5) 31.10	Neuropsychological tests, MMPI, and PAFI before (1-60 days pre-departure) and after (16-221 days) Himalayan or Pamir Mountains expeditions (≥ 5334m)	> 17 days	*t*-test	8848m
A17	Çoksevim et al. (2007; excludes 1200m data)	34 (34/0) 33.50	STAI and BSI at BC (2850m) and higher altitude (3900m) on Mount Erciyes	21 hours	*t*-test	3900m
A18	Delle Fave et al. (2003)	6 (6/0) 29.30	ESM across a Thalay Sagar expedition	26 days	*t*-test	Not reported
A19	Demirhan (2005)	620 (420/200) Age not reported	Single questionnaire item assessing perceived risk in mountaineering[2]	Cross-sectional	Two-way ANOVA	Not reported
A20	Egan and Stelmack (2003)	39 (38/1) 40.20	EPQ-R	Cross-sectional	*t*-test Correlation analysis	8848m
A21	Ewert (1985)	460 (372/78)[3] 29.65	40-item measure of motives for mountaineering	Cross-sectional	Principal component factor analysis *t*-test	Not reported
A22	Ewert (1994)	360 (327/25)[3] 32.30	50-item measure of motives for mountaineering, and ratings of experience and skill	Cross-sectional	Kendall tau correlation Principal component factor analysis One-way ANOVA	Not reported
A23	Faith and Šípoš (1975)	11 (gender not reported) Age not reported	Memory tested before, the morning of, and after an expedition	> 1 day	ANOVA	Not reported
A24	Gomá-i-Freixanet (1991)	27 (27/0) 33.44	SSS-V, EPQ, IVE impulsiveness scale, CPI socialisation scale, SP, and SR	Cross-sectional	ANOVA	> 8000m
A25	Gürer (2015)	315 (245/70)	PSI	Cross-sectional	*t*-test One-way ANOVA	Not reported
A26	Guszkowska and Boldak (2010)	20 (20/0) Age not reported	Polish SSS-IV	Cross-sectional	One-way ANOVA	Not reported
A27	Harkensee and Hillebrandt (2019)	67 (59/6/2) 30 to ≥ 70	WHOQOL-BREF and a measure of PTSD	Cross-sectional	Frequency statistics	8848m
A28	Iida et al. (1982)	4 (4/0) 20.50	Executive function and memory tests before, during (BC before and after 4900m), and after a K-13 expedition	> 7 days	Not reported	6450m
A29	Jack and Ronan (1998)	22 (18/4) 29.00	SSS-V and IVE impulsiveness scale	Cross-sectional	ANCOVA	Not reported
A30	Karinen and Tuomisto (2017)	9 (9/0) 37.70	Short Finnish POMS, STAI, CPST, and NCT before (-2 days), during (four at MEBC = 5380m), and after (+4 days) a ME climb. AAQ-II completed post-expedition (+4 days)	69 days	ANOVA *t*-test	8848m
A31	Kramer et al. (1993)	20 (18/2) 31.75[1]	Perceptual speed, spatial ability, memory, response selection speed, and psychomotor tests before, during (4328m), and after climbing Denali (*M* altitude reached ≥ 5844m)	12-26 days	Split-plot ANOVA	6400m
A32	Lieberman et al. (1995)	5 (5/0) 35-52	Speech motor control, syntax, verbal fluency, complex attention, and cognitive flexibility tested during (5300m pre- and post-ascent, 6300m, and 7150m) a ME climb	Not reported	ANOVA Correlation analysis	8848m

A33	Machado and Andrade (1985)	12 (12/0) 22-42	Attention, memory, intellectual, and perception tests before (-15 days) and during (5200m) a Himalayan expedition	> 30 days	*t*-test	5200m
A34	Magni et al. (1985)	22 (20/2) 34.20	16PF and SCL-90 before departing to climb K-2	Cross-sectional	*t*-test Welch's *t*-test	Not reported
A35	Malle et al. (2016)	4 (4/0) 29.20	Memory and attention assessed repeatedly during (1050m-7100m) and after (+20 and + 62 days) a successful summit attempt on Shishapangma	111 days	Friedman repeated measures Wilcoxon matched pairs test	8043m
A36	Merz et al. (2013)	32 (25/7) 43.00	Unilateral inattention, verbal fluency, non-verbal fluency, and visuo-motor tests before, during (5533m and 6265m), and after (+ 3 months) a Muztagh Ata expedition	> 110 days	Mixed design ANOVA	7546m
A37	Migdal (1990)	30 (25/5) Age not reported	Polish SSS, STAI fear subscale, and a RPQ designed by the research team	Cross-sectional	*t*-test Wilcoxon Cochran-Cox Correlation analysis	Not reported
A38	Milne and Gray (1983)	3 (3/0) 26-47	Psychomotor functioning, reasoning, memory, concentration, and DM tests before, during (> 4500m), and after (≤ 14 days) an expedition (7800m summit)	≥ 50 days	Wilcoxon matched pairs test	7803m
A39	Missoum et al. (1992)	100 (80/20) Age not reported	STAI and BAS before (2-3 months) a Himalayan expedition and recorded AMS symptoms during the climb	Not reported	*t*-test	Not reported
A40	Nelson (1982)	20 (16/4) 23.5	SCL-90, ISE, and LEQ, and visuo-motor and executive function tests prior to and during (3810m and 5000m) a climb on Denali	25 days	ANOVA Correlation analysis	5000m
A41	Nelson et al. (1990)	12 (9/3) Age not reported	Memory tests and reported metacognition about memory before (1200m), during (MEBC, 6500m, 6500m or 7100m, and MEBC), and after (+ 1 week after highest camp) a ME expedition	> 39 days	ANOVA Friedman chi square	6400m
A42	Noël-Jorand et al. (2001)	10 (10/0) Age not reported	Hand Test at the beginning of an expedition in the Karakorum	Cross-sectional	Chi-squared test Kruskal-Wallis test	6500m
A43	Nursyadiq and Manohar (2013)	124 (77/47) 21-40	SSS	Cross-sectional	*t*-test	Not reported
A44	Pagani et al. (experiment 2; 1998)	7 (gender not reported) Age not reported	Learning tests at Kangchenjunga BC (5350m) before and after acclimatising (exposed to 7300m altitude)	15-18 days	ANOVA	7300m
A45	Petiet et al. (1988)	8 (0/8) 33.80	Complex problem solving, mental efficiency, memory, expressive verbal, and psychomotor tests before, during (4500m), and after (*M* = 7 days post-expedition) a Mount Kongur expedition SRI and MAAC-R before, during (BC and > 5200m), and after (*M* = 7 days post-expedition) the same expedition	52 days	Wilcoxon signed-ranks test Quade test	6248m
A46	Regard et al. (1989)	8 (7/1) 36.00	Attention span, concentration, short-term memory, cognitive flexibility, visuospatial perception, and psychomotor tests	Cross-sectional	ANOVA	> 8500m
A47	Rossi and Cereatti (1993)	20 (gender not reported) 32.3	SSS-V	Cross-sectional	ANOVA	Not reported
A48	Ryn (1971)	30 (20/10) 33.67	16PF, clinical psychopathological tests, and "information was collected about emotional states during climbing" (p. 456)	Cross-sectional	Not reported	7000m
A49	Savage et al. (2020)	91 (76/15) 33.24[1]	FFPI and an experimental task assessing risk aversion	Cross-sectional	*t*-test *F*-tests Correlation analysis	5364m

A50	Shukitt-Hale et al. (1990)	7 (7/0) Age not reported	POMS during (2225m twice, 2530m, 3080m, and 3630m) a climb on Mount Sanford	7 days	Repeated measures ANOVA	3630m
A51	Smith, Kinnafick et al. (2017)	83 (72/11) 42.54	PGTI, SVS, BRS, and BFI, and a single item assessing perceptions of expedition stress in relation to a recent expedition (*M* = 28 months ago)	Cross-sectional	*t*-test Correlation analysis Hierarchical multiple regression	Not reported
A52	Smith, Sandal et al. (2017)	59 (52/7) 43.00	PVQ	Cross-sectional	Kruskal-Wallis test	Not reported
A53	Sommer and Ehlhert (2004)	552 (540/12) 44.04	PDS, GHQ-28, and SoC-29	Cross-sectional	Mann-Whitney *U* test Correlation analysis Stepwise linear regression analysis	Not reported
A54	Stück et al. (2005)	8 (6/2) Age not reported	EI before, during (5400m), and after a Cho-Oyo expedition	22 weeks	Single-case descriptive analysis	8000m
A55	Woodman et al. (Study 2; 2010)	24 (24/0) 32.00	PAIRS and TAS-20	Cross-sectional	Single-factor randomized ANOVA	Not reported
Qualitative						
B1	Burke and Orlick (2003)	10 (7/3) 38.20	Interviews exploring mental strategies used climbing ME	Cross-sectional	Thematic analysis	8848m
B2	Burke et al. (2008)	6 (5/1) 50.00	Multiple interviews on cognitive dissonance and participant experience during and after attempting to climb ME Observations	3 months	Content analysis	8848m
B3	Burke et al. (2010)	4 (4/0) 31.75	Multiple interviews with recreational and experienced mountaineers while climbing ME Observations	3 months	Adapted interpretational qualitative analysis	8848m
B4	Crust et al. (2016)	14 (10/4) 44.40	Phenomenological interviews exploring MT and DM	Cross-sectional	Inductive content analysis	> 8000m
B5	Crust et al. (2019)	17 (13/4) 45.10	Phenomenological interviews exploring MT behaviours	Cross-sectional	Psychological-phenomenological analysis	> 8000m
B6	Davidson (2012)	22 (14/8) Age not reported	Biographical narrative interviews exploring the experience of mountaineering	Cross-sectional	Narrative analysis	Not reported
B7	Pereira (2005)	19 (18/1) 36.00	Interviews exploring perceptions of risk	Cross-sectional	Content analysis	8848m
B8	Swann et al. (2016)	10 (9/1) 42.30	Phenomenological interviews exploring the experience of surviving the 2015 earthquake on ME and the role of MT	Cross-sectional	Psychological-phenomenological analysis	8000m
Mixed methods						
C1	Bratton et al. (1983)	15 (15/0) Age not reported	Interviews prior to and after a ME expedition Ratings of personal feelings towards other members of the team before, during, and after a ME expedition	> 2 months	Social network analysis Wilcoxon matched pairs sign test	8848m

C2	Brugger et al. (1999)	8 (7/1) 35.9	Interview exploring "extraordinary mental phenomena" experienced in mountaineering following a "comprehensive physiologic, neurologic, and neuropsychological evaluation" (p. 68)	Cross-sectional	Descriptive statistics Correlation analysis Qualitative analysis not reported	8848m
C3	Emerson (1966)	15 (15/0) Age not reported	Daily diary Field notes compiled by the researcher Group discussion and radio dialogue recordings	92 days	Chi square ANOVA	8848m
C4	Lester (1983)	17 (17/0) Age not reported	Interviews, observations, and questionnaires before a ME expedition Interviews, observations, and ratings of team members during the expedition	5 months	Not reported	8848m
C5	Ryn (1988)	80 (70/10) 35.00	16PF and "other psychological tests", interviews, and observations of "the mental state of the alpinists" (p. 164)	Cross-sectional	Not reported	7000m
C6	Wagstaff and Weston (2014)	12 (11/1) 36.00	Interviews before and after an Antarctic expedition exploring emotion regulation Diary ratings of cognitive and emotional experiences, CERQ, and two ERQ items daily	2 months	Content analysis Correlation analysis *t*-tests Mediated regression analysis	Not reported

Notes: (1) weighted mean average calculated; (2) data in relation to all other leisure activities were removed; (3) it is recognised that this does not add up to the total sample size, but this was not explained in the original study; (4) abbreviations are used as follows: 16PF = Sixteen Personality Factor Questionnaire; AAQ-II = Acceptance and Action Questionnaire-II; AMS = acute mountain sickness; BAS = Scale of Behavioural Adaptation to Stress; BC = basecamp; BFI = Big Five Inventory; BIDR = Balanced Inventory of Desirable Responding; BRS = Brief Resilience Scale; BS = boredom susceptibility; BSI = Brief Symptom Inventory; CERQ = Cognitive Emotion Regulation Questionnaire; CPI = California Psychological Inventory; CPST = Colorado Perceptual Speed Test; DM = decision-making; EIS = Emotional Intelligence Scale; EPQ = Eysenck Personality Questionnaire; EPQ-R = Eysenck Personality Questionnaire-Revised; ER = emotion regulation; ERQ = Emotion Regulation Questionnaire; ESM = Experience Sampling Method; FFPI = Five Factor Personality Inventory; FPI-114 = Freiburg Personality Inventory-114; FREI = French Risk and Excitement Inventory; GHQ-28 = General Health Questionnaire-28; ISE = Impact of Event Scale; IVE = Impulsiveness-Venturesomeness-Empathy Questionnaire; LEQ = Life Events Questionnaire; MAAC-R = Multiple Affect Adjective Checklist-Revised; ME = Mount Everest; MEBC = Mount Everest Basecamp; MMPI = Minnesota Multiphasic Personality Inventory; MT = mental toughness; NCT = Number Comparison Test; OQ-II = Opinion Questionnaire II; PAFI = Patient Assessment of Own Functioning Inventory; PAIRS = Personal Agency in Interpersonal Relationships Scale; PDS = Posttraumatic Stress Diagnostic Scale; PGTI = Post-Traumatic Growth Inventory; PMS = Pearlin Mastery Scale; PNEI = Positive and Negative Emotionality Inventory; PNES = Positive and Negative Emotions Scale; POMS = Profile of mood states; PSI = Problem Solving Inventory; PTSD = post-traumatic stress disorder; PVQ = Portrait Values Questionnaire; RPQ = Risk Perception Questionnaire; RT5 = Risk Test 5; SCL-90 = Symptom Checklist-90; SEAS = Sensation seeking, emotion regulation, and agency scale; SoC-29 = Sense of Coherence-29; SP = Susceptibility to Punishment Scale; SR = Susceptibility to Reward Scale; SRI = Self-rating Inventory; SSS = Sensation Seeking Scale; SSS-IV = Sensation Seeking Scale- IV; SSS-V = Sensation Seeking Scale-V; STAI = State Trait Anxiety Inventory; SVS = Subjective Vitality Scale; TAS-20 = Toronto Alexithymia Scale; TIPI = Ten-item Personality Inventory; WHOQOL-BREF = World Health Organization Quality of Life Questionnaire.

Table 2: Study quality scores for each article included in the review.

Article	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	Total %
Quantitative																
Anicich et al. (Study 1; 2014)	3	2	3	0	3	3	1	1	1	2	n/a	3	1	0	0	54.76
Aras et al. (2018)	2	3	2	0	1	2	1	0	0	2	n/a	1	1	0	1	38.10
Barlow et al. (2013)	3	3	3	1	2	2	3	1	2	3	n/a	3	2	0	2	71.43
Bassi and Delle Fave (2010)	2	3	3	2	1	3	2	1	3	2	n/a	2	2	2	2	71.43
Bektaş (2013)	1	2	2	0	1	3	1	0	2	1	n/a	2	0	0	1	38.10
Breivik (1996)	1	2	3	0	2	1	3	1	2	3	n/a	3	0	0	0	50.00
Burnik et al. (2002)	1	3	1	0	1	1	0	0	0	2	n/a	1	0	0	1	26.19
Burnik et al. (2005)	1	2	3	0	2	1	0	1	1	2	n/a	2	0	0	0	35.71
Burnik et al. (2008)	2	2	1	0	1	1	1	0	1	3	n/a	2	0	0	0	33.33
Burns et al. (2020)	2	2	3	0	3	2	1	2	0	2	n/a	2	0	0	0	45.24
Castanier et al. (2011)	3	3	1	0	2	2	2	1	3	3	n/a	3	2	0	2	64.29
Cavaletti and Tredici (1993)	1	1	1	0	1	2	1	1	0	2	n/a	2	0	0	1	30.95
Cavaletti et al. (1990)	0	1	1	1	1	1	0	1	0	1	n/a	1	0	1	2	26.19
Clark et al. (1983)	1	2	3	0	2	2	2	1	0	2	n/a	2	1	1	0	45.24
Çoksevim et al. (2007)	1	2	2	0	1	2	0	0	0	1	n/a	2	0	0	0	26.19
Delle Fave et al. (2003)	3	2	3	1	2	3	3	2	2	3	n/a	3	3	0	2	76.19
Demirhan (2005)	1	2	1	0	3	1	0	1	3	1	n/a	2	1	1	1	42.86
Egan and Stelmack (2003)	2	2	2	0	2	1	0	1	0	2	n/a	1	0	0	0	30.95
Ewert (1985)	1	3	2	0	2	1	1	2	3	2	n/a	2	1	0	0	47.62
Ewert (1994)	3	3	3	1	3	2	2	2	2	3	n/a	3	2	1	1	73.81
Faith and Šípoš (1975)	2	0	1	0	1	1	0	0	0	2	n/a	2	0	0	0	21.43
Gomá-i-Freixanet (1991)	3	2	1	0	3	1	0	2	0	3	n/a	3	1	0	0	45.24
Gürer (2015)	1	1	2	0	2	2	0	1	2	1	n/a	2	0	0	0	33.33
Guszkowska and Boldak (2010)	3	2	1	0	2	1	2	1	2	2	n/a	2	0	0	2	47.62
Harkensee and Hillebrandt (2019)	0	3	3	0	1	2	1	3	0	2	n/a	1	0	2	1	45.24
Iida et al. (1982)	1	1	2	0	1	2	1	1	0	0	n/a	1	0	0	0	23.81
Jack and Ronan (1998)	3	3	2	1	3	3	3	3	3	3	n/a	2	2	0	3	80.95
Karinen and Tuomisto (2017)	1	2	3	0	1	3	1	1	1	3	n/a	3	1	0	2	52.38
Kramer et al. (1993)	3	3	2	1	2	2	2	0	0	3	n/a	2	0	0	0	47.62
Lieberman et al. (1995)	2	0	2	0	1	3	1	1	0	2	n/a	2	0	0	2	38.10
Machado and Andrade (1985)	0	1	1	0	1	1	2	1	0	2	n/a	2	0	0	0	26.19
Magni et al. (1985)	0	1	2	0	1	2	1	1	0	2	n/a	2	1	0	1	33.33
Malle et al. (2016)	1	3	3	0	1	2	2	0	0	3	n/a	3	1	0	1	47.62
Merz et al. (2013)	2	2	2	0	2	3	3	1	0	3	n/a	2	1	0	2	54.76
Migdal (1990)	2	2	1	1	2	1	1	0	0	2	n/a	2	2	0	0	38.10
Milne and Gray (1983)	0	1	1	0	1	1	0	1	0	1	n/a	1	0	0	1	19.05
Missoum et al. (1992)	1	2	1	0	3	2	0	0	0	2	n/a	1	0	0	0	28.57
Nelson (1982)	0	0	2	0	2	1	3	0	2	2	n/a	2	0	0	0	33.33
Nelson et al. (1990)	1	1	2	0	1	2	3	0	1	3	n/a	1	0	0	1	38.10
Noël-Jorand et al. (2001)	2	3	2	0	2	2	2	0	0	3	n/a	3	3	0	0	52.38
Nursyadiq and Manohar (2013)	3	1	3	1	3	1	2	2	0	3	n/a	2	1	0	1	54.76
Pagani et al. (Experiment 2; 1998)	2	2	2	0	2	2	2	1	0	2	n/a	3	1	0	0	45.24
Petiet et al. (1988)	1	2	2	0	2	3	1	1	0	3	n/a	3	1	0	2	50.00
Regard et al. (1989)	1	1	2	0	1	2	2	0	0	2	n/a	1	1	0	1	33.33

Rossi and Cereatti (1993)	3	2	2	0	2	1	1	1	0	2	n/a	2	1	0	0	40.48
Ryn (1971)	1	1	1	0	1	1	0	1	0	1	n/a	0	0	0	1	19.05
Savage et al. (2020)	3	3	3	0	2	3	3	2	3	2	n/a	3	2	0	2	73.81
Shukitt-Hale et al. (1990)	0	2	2	0	1	2	1	0	0	2	n/a	2	0	0	0	28.57
Smith, Kinnafick et al. (2017)	3	3	2	1	2	3	3	1	3	3	n/a	3	3	0	3	78.57
Smith, Sandal et al. (2017)	3	3	2	1	2	1	2	0	0	3	n/a	3	3	0	2	59.52
Sommer and Ehlhert (2004)	2	2	2	0	3	1	1	3	0	3	n/a	2	2	0	2	54.76
Stück et al. (2005)	0	1	2	0	1	2	0	0	0	2	n/a	1	0	0	0	21.43
Woodman et al. (Study 2; 2010)	3	2	3	1	1	2	2	2	3	3	n/a	3	2	0	3	66.67
Qualitative																
Burke and Orlick (2003)	1	2	3	0	3	2	1	1	n/a	n/a	1	3	2	0	0	48.72
Burke et al. (2008)	3	3	3	0	2	3	3	2	n/a	n/a	3	2	2	2	2	76.92
Burke et al. (2010)	3	3	3	0	2	3	3	1	n/a	n/a	3	3	1	0	1	66.67
Crust et al. (2016)	3	3	3	0	3	3	3	3	n/a	n/a	3	3	3	0	2	82.05
Crust et al. (2019)	3	3	3	0	3	3	3	2	n/a	n/a	3	3	3	2	2	84.62
Davidson (2012)	3	2	2	1	3	2	3	2	n/a	n/a	3	3	3	1	1	74.36
Pereira (2005)	2	2	1	0	2	2	0	1	n/a	n/a	2	2	1	2	0	43.59
Swann et al. (2016)	3	3	3	0	3	3	3	3	n/a	n/a	3	3	3	0	2	82.05
Mixed methods																
Bratton et al. (1983)	0	1	1	0	1	1	0	1	0	1	0	1	0	0	0	15.55
Brugger et al. (1999)	0	1	2	0	1	1	0	0	0	1	1	1	1	0	1	22.22
Emerson (1966)	3	3	3	0	2	2	1	1	0	1	2	1	0	0	1	44.44
Lester (1983)	1	3	3	0	2	2	0	0	0	2	1	0	0	0	0	31.11
Ryn (1988)	2	2	2	0	2	1	1	0	0	2	0	1	1	0	0	31.11
Wagstaff and Weston (2014)	3	3	3	1	2	3	3	3	1	3	3	3	3	0	3	82.22
Totals																
Quantitative articles	1.64	1.94	2.02	0.25	1.74	1.83	1.36	0.94	0.85	2.21	n/a	2.06	0.87	0.15	0.92	44.56
Qualitative articles	2.63	2.63	2.63	0.13	2.63	2.63	2.38	1.88	n/a	n/a	2.63	2.75	2.25	0.88	1.25	69.87
Mixed methods articles	1.50	2.17	2.33	0.17	1.67	1.67	0.83	0.83	0.17	1.67	1.17	1.17	0.83	0.00	0.83	37.78
All included articles	1.75	2.04	2.12	0.22	1.84	1.91	1.43	1.04	0.78	2.15	2.00	2.06	1.03	0.22	0.96	46.98

Note: (a) in line with guidelines for the QATSDD (Sirriyeh et al., 2012), the criteria for quality assessment are: (1) explicit theoretical framework; (2) statement of aims/objectives in main body of report; (3) clear description of research setting; (4) evidence of sample size considered in terms of analysis; (5) representative sample of target group of a reasonable size; (6) description of procedure for data collection; (7) rationale for choice of data collection tools; (8) detailed recruitment data; (9) statistical assessment of reliability and validity of measurement tools (quantitative only); (10) fit between stated research question and method of data collection; (11) fit between stated research question and format and content of data collection tool (e.g., interview schedule); (12) fit between research question and method of analysis; (13) good justification for analytical method selected; (14) assessment of reliability of analytical process (qualitative only); (15) evidence of user involvement in design; and (16) strengths and limitations critically discussed; (b) the scoring criteria for the assessment tool correspond to the following labels: 0 = *not at all*; 1 = *very slightly*; 2 = *moderately;* and 3 = *complete*; (c) criterion 14 was excluded due to recent criticism of strategies for judging the quality of qualitative research in sport and exercise (Smith & McGannon, 2018); (d) for the sake of parsimony, studies by Barlow et al. (2013) were allocated a single study quality score.

Table 3: Descriptive themes, codes, sources, and summary of synthesised findings for personality characteristics of mountaineers (analytical theme 1)

Descriptive themes	Code	Sources	Summary of synthesized findings cited in code sources
Big five personality traits	Agreeableness	A4, A49, A51	***Mountaineers versus non-mountaineers*** 1/3 studies found higher scores in mountaineers (A51). 1/3 studies found a negligible difference (A4). 1/3 studies found lower scores in mountaineers (A49).
	Conscientiousness	A4, A49, A51	***Mountaineers versus non-mountaineers*** 2/3 studies found higher scores in mountaineers (A4, A51). 1/3 studies found a negligible difference (A49).
	Extraversion	A4, A8, A10, A20, A24, A49, A51	***Mountaineers versus non-mountaineers*** 4/7 studies found higher scores in mountaineers (A4, A20, A24, A51). 2/7 studies found negligible differences (A8, A49). 1/7 studies found lower scores in mountaineers (A10).
	Neuroticism[1]	A4, A10, A20, A24, A34, A49, A51	***Mountaineers versus non-mountaineers*** 1/7 studies found higher neuroticism in mountaineers (A49). 1/7 studies found a negligible difference (A34). 5/7 studies found lower scores in mountaineers (A4, A10, A20, A24, A51).
	Openness to experience	A4, A49, A51	***Mountaineers versus non-mountaineers*** 2/3 studies found higher scores in mountaineers (A49, A51). 1/3 studies found a negligible difference (A4).
Mental toughness	Benefits and drawbacks of mental toughness	B1, B4, B5, B8	Mental toughness was regarded as important for: success in Mount Everest summiteers (B1); coping responses after traumatic events (B8); and making decisions on whether to continue or abandon a summit attempt in crisis situations (B4). Mental toughness was also considered beneficial for improving safety, as mentally tough mountaineers were more vigilant and engaged in more comprehensive risk management processes than less mentally tough mountaineers (B4). Mental toughness, however, can have drawbacks when combined with inexperience, as mountaineers can become 'goal-obsessed' and persist for too long, thus threatening safety (B4).
	Characteristics of mental toughness	B1, B4, B5, B8	Characteristics of mentally tough mountaineers included: the ability to endure emotional discomfort and continue to climb at high altitudes (B1, B4, B5, B8); calmness in crisis situations (B8); rational and flexible decision-making (B4); and demonstrating pragmatic perseverance (B5).
Risk-taking	Importance of experience	B6, A19, B7, A49	Experienced mountaineers outlined that they were less likely to take risks after gaining experience compared to their younger selves (B6, B7). A small, non-significant inverse relationship was found between years of experience and willingness to take risks in Mount Everest mountaineers (A49). Lower perceptions of risk found in expert versus less experienced mountaineers (A19).
	Impulsivity	A10, A24, A29	***Mountaineers versus controls or low-risk groups*** 1/3 studies found higher scores in mountaineers (A29). 2/3 studies found negligible differences (A24, A29). 2/3 studies found lower scores in mountaineers (A10, A29). ***Mountaineers versus high-risk groups*** 1/2 studies found higher scores in mountaineers (A29). 2/2 studies found lower scores in mountaineers (A24, A29).
	Psychoticism	A20, A24, A34, A17, A40	***Mountaineers versus controls or low-risk groups*** 2/3 studies found higher scores in mountaineers (A20, A34). 1/3 studies found a negligible difference (A24). ***Changes during expeditions*** 2/2 studies found increases from earlier-to-later stages in expeditions (A17, A40).
	Risk-taking attitudes	B3, B4, B6, B7	Mountaineers explained an awareness of the risks of the activity, but outlined that the challenges faced were important for their sense of self and enjoyment (B3, B4, B6, B7). Experienced mountaineers referred to risk in a reflexive manner (B4, B6), but seek to reduce risk and avoid danger (B4, B5, B6).
	Sensation-seeking	A2, A4, A8, A11, A24, A26, A29, A37, A43, A47, A45	***Mountaineers versus controls or low-risk groups*** 6/6 studies found higher scores in mountaineers (A4, A8, A24, A29, A37, A47). ***Mountaineers versus other high-risk sport athletes*** 3/5 studies found higher scores in mountaineers (A26, A29, A47). 3/5 studies found negligible differences (A4, A24, A26). 1/5 studies found a lower score in mountaineers (A29).
Social aspects of personality	Managing relationships and social interactions	C4, A42, A48, C5, A55, B5, C6	There is a tendency for mountaineers to: be more reserved (A48, C5); withdraw from others (A42); lack interest in social interactions (C4); and have significantly more difficulties maintaining partner relationships (A55). Withdrawal was reported as a coping mechanism for dealing with conflict (C6) and was used to facilitate introspection when mountaineers were under mental strain (B5).

Note: (1) three studies (A4, A34, A49) assessed 'emotional stability', the opposite pole of neuroticism. For the sake of parsimony, we have interpreted these findings in terms of neuroticism (i.e., higher neuroticism = lower emotional stability and vice versa); (2) further supporting data are presented in Supplementary data 6 and Supplementay data 7.

Table 4: Descriptive themes, codes, sources, and summary of synthesised findings for psychological experiences in mountaineering (analytical theme 2)

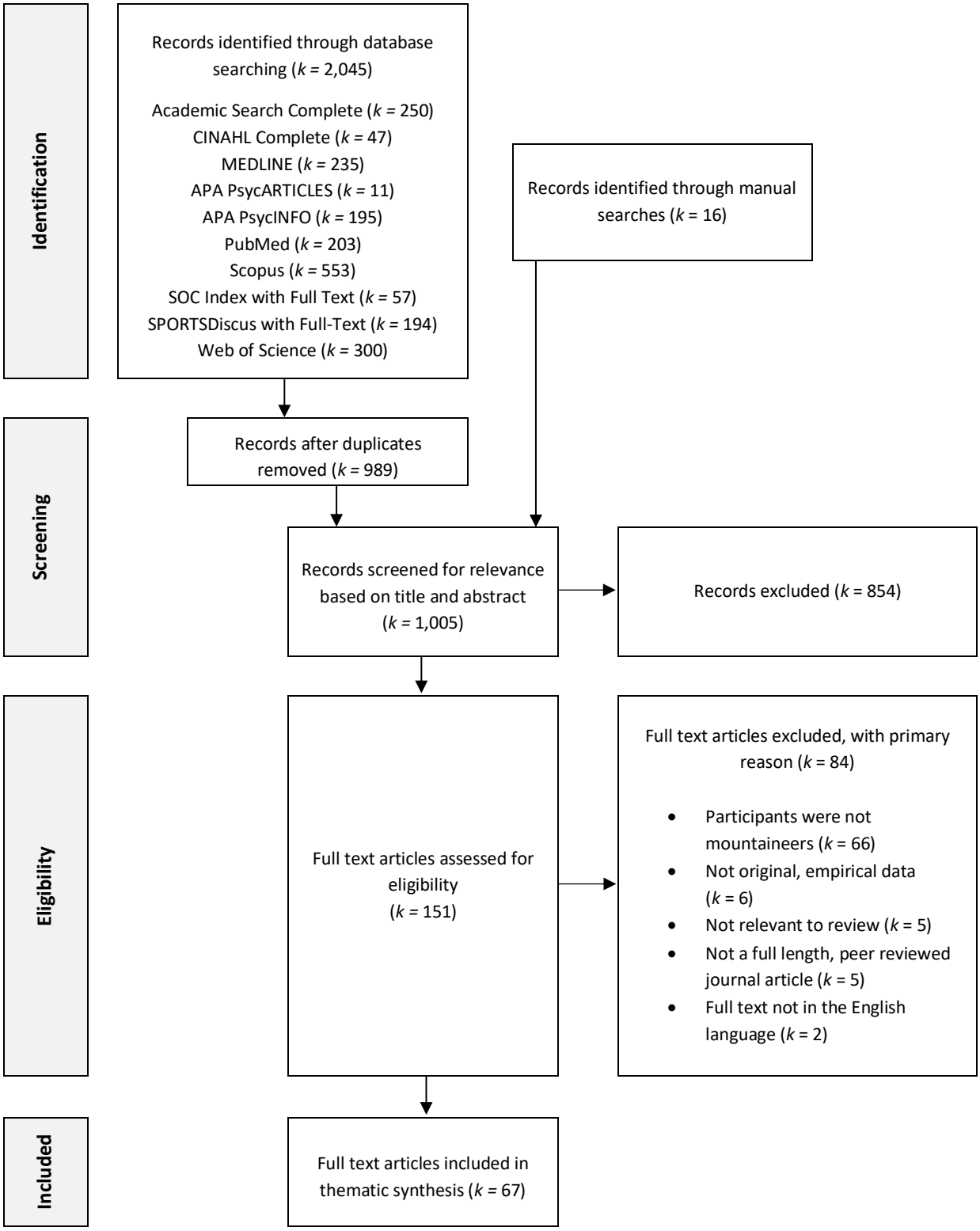
Descriptive theme	Code	Sources	Summary of synthesised findings cited in code sources
Affective phenomena	Positive affective responses	A3, A5, A6, A13, A18, A30, A45, A50, B3, B7, B4, C6	Feelings of happiness were commonly reported during mountaineering (B3, B7, C6). Happiness and enjoyment were attributed by many to the opportunities for adventure and extreme challenges involved (B3, B4). 2/2 cross-sectional studies found significantly higher agentic emotion regulation after participating in mountaineers versus low-risk controls (A3, A5).
	Negative affective responses	A6, A13, A18, A30, A48, A50, B3, B8, C5, C6	Unpleasant emotions were reported less frequently than pleasant emotions (C6). Fear was triggered by concerns for personal safety (B3, B8) and fear of failure (B3). 2/2 studies found an increase in fatigue and decrease in vigor at higher altitudes after the most physically demanding periods during expeditions (A30, A50). A large decline in mood was found from before-to-during a weather emergency (A6).
Cognitive phenomena	Agency	A3, A4, A5, B3, B5, B6, B7, B8, C6	Mountaineers seek to feel a sense of agency and exert control over the situations they face (B5, B6, B7, B8). 2/2 studies found higher experience of agency whilst participating in mountaineers compared to low-risk controls (A3, A5).
	Confidence	A6, A18, B1, B3, B4, C6	Sources of confidence included: developing metacognitive knowledge (B3); extensive preparation; reaching short-term goals; and considering lessons from previous setbacks (B1). A setback (weather emergency) triggered a large decline in confidence (A6).
	Decision-making	B2, B4, B5, B6, B7, B8	Mountaineers seek to stay calm and make rational decisions based on logical analysis of the situation (B2, B4, B8) and good judgement (B6). Mountaineers described feelings of psychological discomfort when making decisions concerning continuation (B2, B4). Reported reasons for poor decision-making included: losing a sense of reality and focusing too intensely on the summit (B4); pushing too hard (B4, B6); human errors (B4, B6); inexperience (B4, B6); and poor physical and mental condition (B4, B7).
	Motivation	A3, A5, A6, A12, A18, A21, A22, A48, A52,B3, B4, B6, B7, C3, C4, C5	Mountaineers are motivated by the challenges of mountaineering and overcoming them, as well as the opportunity to test their skills (A48, B3, B4, B5, B7, C5). Mountaineers have a strong desire to feel at one with the mountains (B3) and enjoy being in the natural environment (B4, B6, B7). The physical setting was the most strongly endorsed motive for mountaineers in large-scale quantitative studies (A12, A21). Mountaineers, especially experienced mountaineers, are motivated by the excitement/exhilaration of the activity (A21, A22). The risk *per se* was not considered a strong motivating factor (A12, A22, B7).
	Impact on self-perceptions	A51, B1, B2, B8	Summiting Mount Everest had a positive impact on the lives and confidence of mountaineers (B1). Quantitative evidence of growth was found in mountaineers after expeditions (A51). Most mountaineers reported that mountaineering expeditions increased their appreciation of life (A51), while life perspective changes were attributed to successfully summiting Mount Everest (B1) and surviving a disaster (B8).
	Quality of experience	A6, A18	Optimal experience (operationalized as high challenge-high skills) was the most commonly experienced state during climbing (A18). Optimal experience was reported more before and during a weather emergency, while apathy was most prominent during a weather emergency (A6).
Metacognitive experiences	Metacognitive feelings	B1, B2, B3, B4, B5, B6, B7	Mountaineers described feelings of difficulty (B1, B3), as well as feelings of belief (B1, B3) and feelings of doubt (B4). Feelings of knowing encompassed: knowing when to stop or continue (B2, B4, B6, B7); knowing what strategies to employ (B1, B3); and knowing the meaning of physical sensations (B3, B4).
	Metacognitive judgements and estimates	B2, B3, B4, B6, B7	Metacognitive judgements and estimates included: estimations about risk (versus reward) when making decisions (B2, B4, B6); judgement about performance and progress (B3, B4); and judgements about physical state (B3, B4).
	Metacognitive knowledge	B1, B3, B6	Gaining experience was considered important for developing metacognitive knowledge (B1, B3, B6).
Mental health	Anxiety	A2, A6, A8, A13, A15, A17, A18, A27, A30, A34, A37, A40, A45, A53, A54, C6	***Changes from earlier-to-later stages in expeditions*** 3/6 studies found increases (A17, A40, A45). 4/6 studies found decreases (A2, A30, A45, A54). ***Changes from pre-to-post expedition*** 1/5 studies found an increase (A45). 5/5 studies found decreases (A13, A15, A30, A45, A54). ***Cross-sectional ratings*** 1/4 studies reported a higher score in mountaineers versus controls (A34). 1/4 studies reported a negligible difference between mountaineers and non-mountaineers (A8).

			2/4 studies reported lower scores in mountaineers versus controls (A30, A37). 2/2 studies found low scores in the majority of mountain guides (A27, A53).
	Depression	A10, A15, A16, A17, A27, A30, A34, A40, A45, A48, A50, A53, C5, C6	***Changes from earlier-to-later stages in expeditions*** 3/5 studies found increases (A17, A40, A45). 2/5 studies found negligible changes (A30, A50). 1/5 studies found a decrease (A30). ***Changes from pre-to-post expedition*** 2/4 studies found an increase (A16, A45). 1/4 studies found a negligible change (A15). 1/4 studies found a decrease (A30). ***Cross-sectional ratings*** 2/2 studies found lower scores in mountaineers versus controls (A10, A34). 2/2 studies reported low ratings of depression in mountain guides (A27, A53).
	Obsessive compulsive disorder	A17, A40	2/2 studies found increases from lower-to-higher altitudes (A17, A40).
	Paranoia	A17, A40	2/2 studies found increases from lower-to-higher altitudes (A17, A40).
	Post-traumatic stress disorder	A27, A53, B8	2/2 studies reported low post-traumatic stress disorder scores in mountain guides (A27, A53). Post-traumatic stress disorder was reported by mountaineers after a traumatic event on Mount Everest (B8).
Neuropsychological functioning	Complex attention	A7, A14, A16, A30, A31, A33, A35, A36, A38, A45, A46	***Changes from lower-to-higher altitudes during expeditions*** 3/8 studies found improvements (A30, A35, A45). 3/8 studies found negligible changes (A31, A36, A38). 4/8 studies found deteriorations (A7, A31, A33, A45). ***Changes from pre-to-post expedition*** 4/8 studies found improvements (A16, A35, A36, A45). 6/8 studies found negligible differences (A14, A16, A30, A31, A38, A45). 2/8 studies found deteriorations (A14, A31).
	Executive functions	A14, A16, A28, A32, A33, A38, A40, A45, A46	***Changes from lower-to-higher altitudes during expeditions*** 3/6 studies found improvements (A28, A33, A40). 5/6 studies found negligible changes (A28, A32, A33, A38, A45). 1/6 studies found a deterioration (A40). ***Changes from pre-to-post expedition*** 3/5 studies found improvements (A16, A28, A45). 4/5 studies found negligible changes (A14, A16, A38, A45). 1/5 studies found a deterioration (A45).
	Memory and learning	A14, A15, A16, A23, A28, A31, A32, A33, A35, A38, A41, A44, A45, A46	***Changes from lower-to-higher altitudes during expeditions*** 6/9 studies found improvements (A28, A31, A32, A35, A44, A45). 6/9 studies found negligible changes (A28, A31, A32, A38, A41, A45). 1/9 studies found a deterioration (A33). ***Changes from pre-to-post expedition*** 4/10 studies found improvements (A16, A31, A35, A45). 7/10 studies found negligible changes (A16, A23, A28, A31, A38, A41, A45). 4/10 studies found deteriorations (A14, A15, A16, A45).
	Language	A15, A16, A32, A36, A45	***Changes from lower-to-higher altitudes during expeditions*** 1/3 studies found improvements (A45). 2/3 studies found negligible changes (A32, A45). 2/3 studies found deteriorations (A32, A36). ***Changes from pre-to-post expedition*** 3/4 studies found improvements (A15, A16, A36). 3/4 studies found negligible changes (A15, A16, A36). 1/4 studies found deteriorations (A45).
	Perceptual and motor functions	A15, A16, A31, A32, A33, A36, A38, A40, A45, A46	***Changes from lower-to-higher altitudes during expeditions*** 1/7 studies found improvements (A45). 4/7 studies found negligible changes (A31, A36, A38, A45). 3/7 studies found deteriorations (A32, A33, A40). ***Changes from pre-to-post expedition*** 2/6 studies found improvements (A16, A45). 6/6 studies found negligible changes (A15, A16, A31, A36, A38, A45). 1/6 studies found a deterioration (A45).
Regulatory processes	Planning before mountaineering	B1, B3, B4, B5	Planning for all potential eventualities in the build up to expeditions was considered integral for improving performance and managing obstacles and risk (B1, B3, B4, B5). Mountaineers explained how they considered all potential obstacles that could occur and identified strategies that could be used to equip them for these situations (B1, B3).
	Attentional monitoring	B1, B3, B4, B7	Internally monitored senses reported during mountaineering included: breathing (B1, B3, B4); exertional fatigue (B1, B3, B4, B7); heart beat

			(B1); and exertional pain and discomfort (B1, B3). Outward monitoring centred on mountaineers' awareness of weather conditions and the terrain on the route (B4, B7).
	Distractive strategies during mountaineering	B1, B3, B5, C6	Distractive strategies reported during expeditions included: listening to music (B1, C6); reading (C6); and counting (i.e., steps - B5).
	Self-regulation strategies during mountaineering	A3, A4, A5, A6, B1, B3, B4, B5, B8, C6	Suppression was the most frequently used emotional regulation strategy (C6) and was employed to: maintain focus (B1); enable logical and rational analysis (B4, B8); and avoid interpersonal conflict (C6). Suppressing emotions was positively associated with mental fatigue (C6) and was cited as an antecedent of long-term emotional difficulties after a disaster (B8). Goal setting was a commonly cited strategy, and experienced mountaineers highlighted the importance of adopting short-term, process goals (B1, B3) and recognized the need to adapt their goals in certain circumstances (B3, B8). Other common strategies included acceptance (B3, B4, B5, B8, C6) and imagery (B1, B3, B4).
Group processes	Conflict	B8, C1, C6	Maladaptive responses to expedition events were associated with argumentative behavior and conflict (B8, C6). Poor emotion regulation and fatigue increased the likelihood of conflict (C6). Personality conflicts were associated with poorer interpersonal evaluations in an expedition team (C1).
	Hostility	A17, A40, A45	3/3 studies found increases from earlier-to-later stages in expeditions (A17, A40, A45). 1/3 studies found a decrease from earlier-to-later stages in expeditions (A45).
	Interpersonal sensitivity	A17, A40	2/2 studies found increases from earlier-to-later stages in expeditions (A17, A40). 1/2 studies found a decrease from earlier-to-later stages in expeditions (A40).
	Leadership	A1, B5, B8, C1	Leadership was identified as a key aspect of the organization and initiation of the recovery effort after the 2015 earthquake on Mount Everest (B8). Interpersonal evaluations of an expedition leader were more positive amongst those who experienced a more democratic leadership style versus those you experienced a more autocratic leadership style (C1).
	Social support	B1, B4, B5	Support from climbing partners and expedition team members was considered crucial for overcoming difficulty (B4) and summiting Mount Everest (B1). Choosing trusted climbing partners was valued for increasing safety in extreme environments (B4, B5).

Note: (1) further supporting data are presented in Supplementary data 6 and Supplementary data 7.

Figure 1: Flow diagram illustrating the screening process.



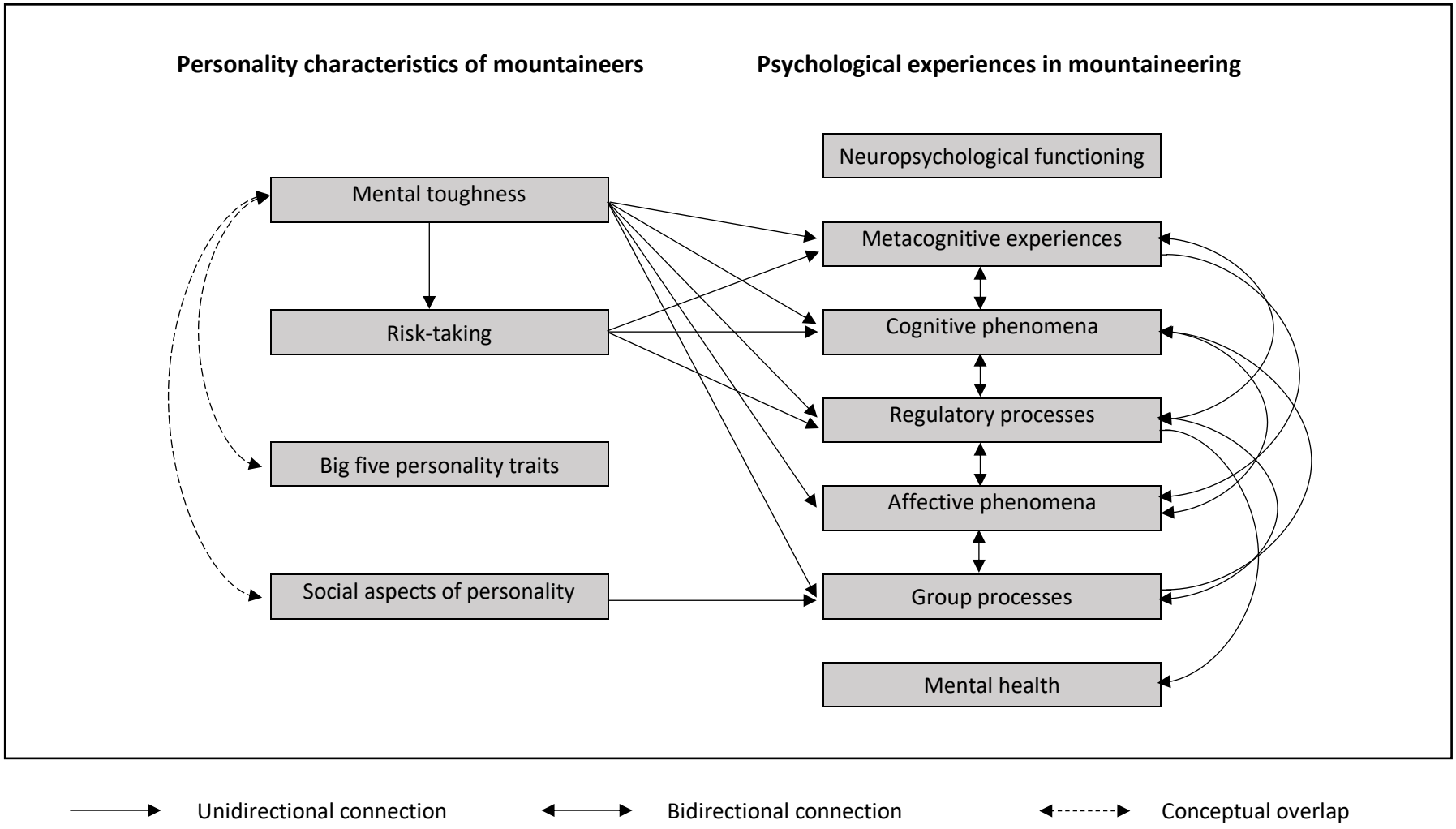


Figure 2: Map depicting connections between analytical and descriptive themes in the synthesis.