

1 **10 years of EPOC: A scoping review of Emotiv's portable EEG device**

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Abstract

16 **BACKGROUND:** Commercially-made low-cost electroencephalography (EEG)
17 devices have become increasingly available over the last decade. One of these
18 devices, Emotiv EPOC, is currently used in a wide variety of settings, including brain-
19 computer interface (BCI) and cognitive neuroscience research.

20 **PURPOSE:** The aim of this study was to chart peer-reviewed reports of Emotiv
21 EPOC projects to provide an informed summary on the use of this device for
22 scientific purposes.

23 **METHODS:** We followed a five-stage methodological framework for a scoping
24 review that included a systematic search using the Preferred Reporting Items for
25 Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-
26 ScR) guidelines. We searched the following electronic databases: PsychINFO,
27 MEDLINE, Embase, Web of Science, and IEEE Xplore. We charted study data
28 according to application (BCI, clinical, signal processing, experimental research, and
29 validation) and location of use (as indexed by the first author's address).

30 **RESULTS:** We identified 382 relevant studies. The top five publishing countries
31 were the United States (n = 35), India (n = 25), China (n = 20), Poland (n = 17), and
32 Pakistan (n = 17). The top five publishing cities were Islamabad (n = 11), Singapore
33 (n = 10), Cairo, Sydney, and Bandung (n = 7 each). Most of these studies used
34 Emotiv EPOC for BCI purposes (n = 277), followed by experimental research (n =
35 51). Thirty-one studies were aimed at validating EPOC as an EEG device and a
36 handful of studies used EPOC for improving EEG signal processing (n = 12) or for
37 clinical purposes (n = 11).

38 **CONCLUSIONS:** In its first 10 years, Emotiv EPOC has been used around the world
39 in diverse applications, from control of robotic limbs and wheelchairs to user

40 authentication in security systems to identification of emotional states. Given the
41 widespread use and breadth of applications, it is clear that researchers are
42 embracing this technology.

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Introduction

45 Electroencephalography (EEG) is a continuous recording of the electrical
46 activity generated by groups of neurons firing in the brain. An EEG typically
47 comprises recordings of activity present at multiple sites on the head, indexed using
48 metal electrodes placed on the scalp. EEG recordings can be inspected by sight for
49 signs of brain dysfunction (e.g., epilepsy), or can be processed to produce spectral
50 analyses of the electrical activity over a period of time, and event-related potentials
51 (ERPs) that reflect the average pattern of electrical activity generated by a particular
52 stimulus (e.g., a speech sound, a face, a written word).

53 EEG is one of the oldest neuroscientific techniques in use today. Since the
54 first human recordings published by Hans Berger in 1929 [see 1, for a history], EEG
55 has become a popular tool for neuroscientists due to its non-invasive nature and
56 high temporal resolution. The technique has matured over the decades due to
57 advances in technology, which has allowed for greater instrument sensitivity and
58 better signal processing techniques. What used to be analogue signals scribed onto
59 rolls of paper are now digital recordings stored on hard drives, ready for processing
60 using a myriad statistical and mathematical techniques.

61 In recent years, one of the biggest evolutions in EEG applications has been
62 the development of consumer-grade devices. Not only do these devices make
63 acquiring EEG signals easier, but they can do so in natural environments outside the
64 traditional laboratory setting. In 2009, a biotech company, Emotiv Systems, released
65 EPOC, a consumer-oriented EEG device. EPOC was originally designed and
66 marketed as a hands-free videogame device, placing it within the class of brain-
67 computer interface (BCI) devices. As one of the first EEG devices available to
68 consumers, EPOC's release demonstrated the feasibility of low-cost neuroimaging

69 outside of research laboratories. The next 10 years saw the EPOC developer re-
70 established as Emotiv Inc., a second iteration of the device called EPOC+, and the
71 market of EPOC evolve to include research applications. Neuroscientists, keen to
72 take advantage of efficiency increases and budget decreases, saw an opportunity in
73 EPOC for user-friendly research at a fraction of the cost of traditional research-grade
74 EEG systems.

75 In the decade since its release, EPOC has been used in hundreds of scientific
76 applications as its ease of setup and low price-point make it an appealing option for
77 researchers and engineers. The first published works using EPOC appeared in
78 2010, describing the use of EPOC in BCI applications [2-4]. In 2011, the first study
79 using for experimental research was published [5]. Two years later, studies
80 validating the use of EPOC in experimental research began to emerge [6-8]. In the
81 years that followed, EPOC appeared in many conference proceedings and journal
82 articles, suggesting its wide adoption as an EEG device. In our laboratory, we have
83 successfully converted the EPOC into an ERP device, which we have validated
84 against a research-grade system [8-10]. In addition, our department has integrated
85 EPOC into the Bachelor of Cognitive and Brain Sciences as a practical
86 demonstration of neuroscience methodology [11].

87 Given the demonstrated validity of the EPOC as a research tool, as well as its
88 low cost, researchers around the world are understandably curious about what the
89 EPOC system can and cannot be used for. This has inspired a number of reviews of
90 EPOC's use in specific domains such as BCI [12-17], cognitive enhancement [18,
91 19], stress detection [20], and education [21]. However, no review has considered
92 the use of the EPOC across multiple domains. In addition, while other reviews have

93 focused on portable EEG devices in general [22-26], none have focused on the
94 EPOC device specifically.

95 With this gap in knowledge in mind, we aimed to carry out a scoping review of
96 studies that have used the EPOC as an EEG and ERP device to understand the use
97 and location of EPOC research to date. We followed the framework put forth by
98 Arksey and O'Malley (27 p. 21) for conducting a scoping review, where, in contrast to
99 a systematic review, a scoping review does not seek to answer a narrowly-defined
100 research question but to examine and describe the “extent, range, and nature of
101 research activity”. We followed the five stages described by Arksey and O'Malley
102 (27), which were:

103 Stage 1: identifying the research question.

104 Stage 2: identifying relevant studies.

105 Stage 3: study selection.

106 Stage 4: charting the data.

107 Stage 5: collating, summarising, and reporting the results.

108 Additionally, we followed the Preferred Reporting Items for Systematic
109 Reviews and Meta-analyses Extension for Scoping Reviews (PRISMA-ScR)
110 guidelines [28]. See supporting information (S1 PRISMA-ScR) for the checklist.

111 **Stage 1: Identifying the Research Question**

112 We sought to answer the question of where (i.e., locations) and how (i.e.,
113 applications) EPOC has been used in research settings. In addressing this question,
114 we aim to facilitate decision-making about EPOC useability and expect this review
115 may be particularly beneficial for researchers who are searching for inexpensive
116 neuroscience techniques. It may also be useful for clinicians in the development of
117 BCI-assisted technologies that support people with physical limitations.

118 **Emotiv EPOC**

119 There have been two versions of Emotiv's device, EPOC and EPOC+. The
120 primary difference is that EPOC+ can capture data at 128 Hz and 256 Hz sampling
121 rates whereas EPOC samples at 128 Hz only. We reviewed projects using both
122 devices in this scoping review, but for simplicity we will refer to both versions as
123 EPOC.

124 **Stage 2: Identifying Relevant Studies**

125 The first author conducted a systematic search of the literature by retrieving
126 records from the following online bibliographic databases: (a) PsychINFO, (b)
127 MEDLINE, (c) Embase, (d) Web of Science, and (e) IEEE Xplore. These widely-used
128 databases cover a large breadth of fields, including psychology, cognitive science,
129 medicine, and engineering. Searches included peer-reviewed studies conducted with
130 human participants and written in English. Searches included studies published from
131 2009 onwards (i.e., the year EPOC was released). To find records in each database,
132 we used the following search strings in conjunction with wildcards to capture
133 keyword variations: Emotiv, EPOC, electroencephalograph, EEG, event-related,
134 ERP. For example, in PsychINFO we used: (Emotiv OR EPOC) AND
135 (electroenceph* OR EEG OR event-related OR event related OR ERP). The initial
136 search was conducted in June of 2018. A second search was conducted in February
137 of 2019 and a third search was conducted in February 2020.

138 Fig 1 outlines the Preferred Reporting Items for Systematic Reviews and
139 Meta-analyses (PRISMA) flowchart for this review (Moher, Liberati, Tetzlaff, &
140 Altman, 2009). In brief, we identified 724 articles via the database search. This
141 included 249 duplicate articles resulting in 475 articles after removal.

142 **Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses**
143 **(PRISMA) flowchart.**

144 **Stage 3: Study Selection**

145 We excluded twenty-two records for which the full-text could not be retrieved
146 and screened the remaining articles according to the following eligibility criteria: (1)
147 EPOC device used; (2) Actual data collected; (3) Articles published in peer-reviewed
148 journals or conference proceedings. We removed seventy-one studies that failed at
149 least one of these criteria. These included publications in which EPOC appeared as
150 the acronym for *Effective Practice and Organisation of Care*, in which no actual EEG
151 data was collected, which were not written in English, or were literature reviews.

152 The final number of studies included in this review was 382. Of these, 252
153 were conference proceedings and 130 were journal articles. As the conference
154 proceedings in this review meet the criteria of peer review, we did not distinguish
155 between conference proceedings and journal articles. However, Fig 2 provides a
156 breakdown of the types of studies over the years included in this review.

157 **Fig 2. Number of EPOC studies by type from 2010 to 2019.**

158 **Stage 4: Charting the data**

159 We charted the data by recording relevant information from each record. This
160 information included the author(s), year of publication, study location, and aims of
161 the study. We classified each study according to its aim into one of five categories:
162 (1) EPOC used as a BCI device (e.g., control of a wheel chair); (2) EPOC used as a
163 clinical tool (e.g., to assess depression); (3) EPOC used to collect EEG data for
164 developing or refining EEG signal processing techniques (e.g., to reduce artefacts in
165 EEG data streams); (4) EPOC used as a theory development tool (e.g., to examine

166 EEG signatures in cognitive tasks); and (5) studies aimed at validating EPOC as an
167 EEG device (e.g., comparing EPOC to research-grade EEG systems). See Table 1
168 for descriptions and number of studies assigned to each category.

169 **Table 1. Category descriptions and counts of EPOC-related studies**

Category	Description	Conference proceedings	Journal articles	Total
Brain-computer interface	Studies that used EPOC as a means of interacting with a computer or a machine.	212	65	277
Clinical	Studies that used EPOC as a diagnostic or therapeutic device.	3	8	11
Signal Processing	Studies that used EPOC to collect data to develop or refine EEG signal processing or analysis techniques.	7	5	12
Experimental Research	Studies that used EPOC to collect EEG data to answer a neuroscience research question or hypothesis.	21	30	51
Validation	Studies that investigated whether EPOC was a valid EEG device.	14	17	31

170
171 To chart the location of EPOC studies, we used the first authors'
172 corresponding address. To visualise the global distribution of EPOC studies, we
173 obtained latitude and longitude coordinates from a world cities database
174 (<https://simplemaps.com/data/world-cities>). If cities did not have coordinate
175 information in the database, we performed a Google search and entered the
176 coordinates manually. See supporting information (S2 Appendix) for data extracted
177 and charted.

178 **Stage 5: Collating, Summarising, and Reporting the Results**

179 The first three EPOC-related studies were published in the year after its
180 release, 2010. These initial studies were all related to BCI: two P300 classification
181 studies [2, 4] and a robotic arm control study [3]. A year later, 2011, saw the first
182 study published using EPOC for experimental research [5]. This study examined the
183 relationship between EEG, personality, and mood on perceived engagement. The
184 first publications aimed at validating EPOC appeared in 2013 [6-8, 29, 30].

185 Overall, the number of EPOC studies showed a steady increase from 2010 (n
186 = 3) to 2015 (n = 61), after which the numbers fell to 58, 59 and 44 in 2016, 2017,
187 and 2018 respectively, and then increased to 52 publications in 2019 (see Fig 3).

188 While the true reason for this pattern is unknown, it may well reflect a change in the
189 licensing of Emotiv software, which switched to a subscription-based license in 2016
190 (previously the license involved a one-time fee). This increased the cost of the EPOC
191 for research, which may explain the declining in publications in 2015 – 2018. The
192 resurgence in 2019 could be acceptance of the licensing fee as the new standard
193 and being factored into budgets and grant applications. It remains to be seen how
194 this fee structure will impact EPOC use in the future.

195 **Fig 3. Number of EPOC studies from 2010 to 2019 by study application.**

196 **Location**

197 In the years 2009 to 2019, the five countries that published the most EPOC
198 studies were the United States (n = 35), India (n = 25), China (n = 20), Poland (n =
199 17), and Pakistan (n = 17). The five individual cities that published the most EPOC
200 studies were Islamabad (n = 11), Singapore (n = 10), Bandung, Indonesia (n = 7),
201 Cairo (n = 7), and Sydney (n = 7). See Fig 4 for overall global distribution of studies
202 covered by this systematic review.

203 **Fig 4. Global distribution of EPOC studies from 2010 to 2019.**

204 **Applications**

205 **BCI.** BCI applications represented the majority of EPOC studies
206 (approximately 73% of studies in this review). To better characterise BCI studies, we
207 further classified them into four subcategories: (a) biometrics, (b) device control, and
208 (c) state recognition, and (c) general classification. See Table 2 for description of
209 each subcategory.

210 **Table 2. Descriptions and study counts of EPOC-related BCI subcategories.**

BCI Subcategory	Description	Study count
Biometrics	Studies that used EPOC to characterise EEG signatures for identification/authentication of individual users.	11
Device control	Studies that used EPOC to enable control of devices in an individual's environment (e.g., wheelchairs, appliances).	97
State recognition	Studies that used EPOC to recognise human physical, mental, or affective states.	94
General classification	Studies that used EPOC to collect EEG data for the classification of EEG signatures, without explicit applications associated with other BCI subcategories in this table.	75

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212 **BCI biometrics.** Much like a fingerprint or a password, individual brain
213 signatures can identify individuals, granting them access to systems or facilities. As
214 the variation between individuals' brain waves can be quite complex, the use of

215 individual EEG signatures as a biometric indicator represents a promising application
216 of portable EEG technology. A total of 11 studies used EPOC to investigate EEG in
217 the context of user-authentication and security. The earliest biometric EPOC study
218 was published in 2013 and used a P300 speller paradigm to investigate the
219 feasibility of using EEG classification for user authentication [31]. Recently, study
220 designs and classification methods have grown more sophisticated. For example,
221 Moctezuma, Torres-Garcia (32) used feature extraction and classification to
222 distinguish between individuals' EEG signatures while they imagined speaking
223 words. Likewise, Seha and Hatzinakos (33) also employed feature extraction, in this
224 case on auditory evoked potentials, to accurately (> 95%) discriminate between
225 individuals. Compared to BCI studies in general, relatively few EPOC studies have
226 focused on biometry. Nevertheless, there has been a general increase in biometric
227 studies since 2013 and this field represents one of the many practical applications of
228 portable EEG technology.

229 **BCI device control.** The control of external devices, such as prostheses or
230 wheelchairs, is the most straightforward application of EEG-based BCIs. A total of 97
231 studies, representing 35% of BCI studies and 25% of studies overall, used EPOC as
232 a means of controlling or interacting with machines in users' environment. P300
233 spellers are perhaps the most well-known type of BCI interface that fall under this
234 category. P300 speller interfaces exploit the well-documented and robust signature
235 observed as deflection in an ERP waveform in a response to a target stimulus. By
236 capitalising on the P300, a computer can detect when a target letter flashes on a
237 screen thereby allowing selection of letters without physical interaction. Though there
238 were several EPOC studies in this review that investigated traditional P300 speller
239 BCI interfaces [34-37], others harnessed P300 for such purposes as interacting with

240 navigation systems [38] and robotic devices [39]. Suhas, Dhal (40) investigated
241 using ERPs to control a light bulb and a fan, with an eye towards giving physically
242 disabled individuals control of ‘smart’ appliances. Other studies have employed
243 EPOC as a means of controlling robots [41-47], tractors [48], and drones [49].
244 Practical and effective BCI device control using EEG has the potential to benefit a
245 large population, such as individuals who have lost the use of motor functions. For
246 this reason, this area of research has received much attention and it should be
247 expected to continue to do so.

248 **BCI state recognition.** Characterising and identifying cognitive or affective
249 states using EEG is critical for many BCI paradigms and is a hallmark of
250 neurofeedback applications. Many researchers have used EPOC to achieve this. For
251 example, an early EPOC study attempted to recognise EEG patterns when
252 participants imagined pictures [50]. More recent studies have used sophisticated
253 algorithms to identify cognitive states, such as confusion [51], fatigue [52] and
254 emotions [53-55]. Identifying an individual’s mental state can help to improve human
255 performance in demanding situations. For example, Binias, Myszor (56) used an
256 EPOC to develop algorithms aimed at helping pilots respond more quickly to
257 unanticipated events. Studies like these demonstrate that the rapid and accurate
258 identification of cognitive and affective states, even before conscious recognition,
259 may lead to safer roads and skies.

260 **BCI general classification.** A total of 75 BCI studies were not readily
261 classifiable in the above subcategories as they were not concerned with a direct
262 application of research. Rather, these studies aimed to increase the usability of BCI
263 technology through the development and refinement of EEG classification
264 algorithms. For example, Perez-Vidal, Garcia-Beltran (57) collected EEG data with

265 EPOC in order to determine the effectiveness of a machine-learning algorithm for
266 correctly identifying P300 evoked potentials. In this example, direct use of the P300
267 was not directly used for interfacing with a specific device/machine. Rather, the
268 central focus was on the algorithm itself. We categorised these types of studies as
269 general classification studies.

270 **Clinical.** The small form factor and ease of setup make portable EEG devices
271 ideal for use in clinical settings in which the objective is to treat or diagnosis health
272 conditions. Eleven studies in this review used EPOC for this purpose, with six
273 studies aimed at using EPOC specifically for a therapeutic purpose. For example,
274 studies have used EPOC to provide neurofeedback for motor rehabilitation [58, 59]
275 or for the treatment of depression [60] and pain [61, 62]. Five studies used EPOC as
276 a diagnostic tool with the aims of assessing conditions such as depression [63],
277 attention deficit hyperactivity disorder [64, 65], or encephalopathy [66]. Yet another
278 study used EPOC to monitor changes in the nervous system of a group of Turkish
279 researchers who visited Antarctica [67].

280 **Signal processing.** Twelve studies in this review aimed to improve EEG
281 signal processing techniques used with EPOC data. For example, Sinha, Chatterjee
282 (68), Soumya, Zia Ur Rahman (69), and Jun Hou, Mustafa (70) used EPOC to test
283 techniques aimed at reducing EEG artefacts and noise. Additionally, Moran and
284 Soriano (71) compared different techniques for maximising EPOC EEG signal quality
285 while Petrov, Stamenova (72) and Shahzadi, Anwar (73) investigated remote EEG
286 transmission and processing. These studies are important as the signal-to-noise
287 ratio of EEG can be small and techniques aimed at increasing it can broaden the
288 utility of EEG devices. In addition, the increasingly distanced nature of research and

289 clinical diagnostics necessitates the development of effective data transmission
290 pipelines.

291 **Experimental Research.** We identified a total of 51 experimental research
292 studies that used EPOC incidentally to answer questions related to brain function.
293 That is, researchers could have used any EEG device to collect data but they chose
294 EPOC. Most of these studies were directly concerned with investigating EEG
295 signatures related to certain processes, situations, or tasks. Many were cognitive in
296 nature including EEG signatures related to cognitive load [74-77], alertness [78],
297 distraction [79], learning styles [76], semantic association [80-82], and memory [83].
298 Other studies examined EEG signatures related to perception. These included
299 spatial perception [84], taste perception [85], olfactory perception [86], and visual
300 perception [87, 88].

301 Studies examining social phenomena also constituted a large proportion of
302 EPOC research projects. For example, we found studies in which EPOC was used to
303 investigate consumer behaviour and preference [89-92]. Other socially-oriented
304 studies examined the EEG patterns associated with conformity [93], deception [94],
305 perception of quality, [95], and motivation and interest in an educational environment
306 [96].

307 Researchers also used EPOC to better understand ailments or disorders.
308 These types of studies are contrasted with those in the *clinical* category where
309 publications were aimed at *treating* ailments or disorders, rather than *investigating*
310 the ailments or disorders. For example, Askari, Setarehdan (97), Askari, Setarehdan
311 (98) used the device to investigate neural connectivity in autism. Similarly, Fan,
312 Wade (99) used EPOC to collect EEG data with the aim of building models to
313 accurately identify cognitive and affective states in autistic individuals while driving.

314 In addition to autism, other studies examined the EEG signatures associated with
315 bipolar disorder [100] and mild cognitive impairment [101].

316 Many research studies were more action-oriented. These types of studies
317 used EPOC to characterise the EEG signatures associated with video games [102,
318 103], driving [104-106], moving through urban [107] or virtual [108] environments,
319 and performance of specialised tasks [109, 110].

320 **Validation.** Assessing the validity of a device is an important step in
321 establishing its widespread implementation. If an EEG system cannot be
322 demonstrated to accurately capture the data it purports to, then any conclusions
323 drawn from this data are questionable. We identified thirty-one studies that tested the
324 validity of EPOC as a research-grade EEG device. The first EPOC validation studies
325 appeared in 2013. In this year there were five studies assessing the capabilities of
326 EPOC. These studies assessed the accuracy of P300 identification [6], the validity of
327 affect signatures [7], and whether EPOC could be used to collect valid ERPs [8, 29,
328 30]. Another five EPOC validation studies were published in 2014 before peaking in
329 2015 (n = 7) and then declining in 2016, 2017, 2018, and 2019 (n = 4, n = 4, n = 3,
330 and n = 3, respectively).

331 Studies varied in both approach and intended application of the validation.
332 Some did not use a benchmark device with which to compare EPOC. For example,
333 Rodriguez Ortega, Rey Solaz (111) compared EPOC-captured affect signatures to
334 those demonstrated in the literature. Another simply aimed to determine the
335 classification accuracy of EPOC in P300 tasks [112]. However, most studies
336 compared the EPOC to the performance of other research- or consumer-grade EEG
337 devices. Four validation studies compared auditory ERPs between systems [8, 10,
338 113]. Three studies compared visual ERPs between systems [9, 114 McDowell, &

339 Hairston, 2014, 115, 116]. Tello, Müller (117) also conducted a visual-related
340 validation study in which they compared EEG device performance on steady-state
341 visual evoked potential (SSVEP) tasks, while Szalowski and Picovici (118) tested the
342 capacity of EPOC to distinguish between different SSVEP experimental parameters.
343 Melnik, Legkov (119) compared the performance of multiple systems on both visual
344 ERPs and SSVEPs. Also in the visual domain, Kotowski, Stapor (120) examined the
345 capacity of EPOC to collect ERPs of emotional face processing. Takehara,
346 Kayanuma (121) compared the performance of EPOC to another device on capacity
347 to capture event-related desynchronization while Grummett, Leibbrandt (122)
348 conducted a comprehensive validation study that compared EPOC to other devices
349 on power spectra, ERPs, SSVEPs, and event-related
350 desynchronization/synchronisation.

351 Some studies validated EPOC's capacity to measure cognitive indicators with
352 one study comparing devices' capture of cognitive load signatures [123 Sinharay, &
353 Sinha, 2014], and another comparing the performance of systems during cognitive
354 tasks using time and frequency analyses [124]. Likewise, Naas, Rodrigues (125)
355 tested whether EPOC could enhance cognitive performance in neurofeedback tasks.

356 Three studies validated EPOC for BCI use by comparing its performance to
357 other device performance on P300 speller tasks [6, 126, 127]. Two others compared
358 the performance of devices on motor imagery tasks [128, 129]. Finally, Maskeliunas,
359 Damasevicius (130) compared the capacity of devices to recognise mental states.

360 Since 2013, many studies have sought to determine the validity of EPOC.
361 While assessment of the conclusions of these studies are outside the aims of this
362 scoping review, what can be noted is that quantity of studies demonstrates
363 researchers' interest in employing these devices in their work.

364

Limitations

365 This scoping review has some limitations. With nearly 400 records selected,
366 the charting phase represented an enormous undertaking. Although the review
367 employed a systematic methodology using PRISMA guidelines and searching a
368 broad array of databases, it was impossible to include every study that used EPOC.
369 We deliberately omitted common systematic search strategies, such as grey-
370 literature searching, hand searching, and backward citation searching. We did this as
371 inclusion of these strategies would not have added enough value to justify the
372 additional time and resources. We believe this scoping review represents a quality
373 characterisation of EPOC research and satisfies the stated aims of the project. In
374 addition, like all scientific reviews, its success depends on the search terms. If a
375 publication did not contain 'Emotiv' or 'EPOC' in the title, abstract, or keywords, then
376 it did not appear in our search. We could have overcome this limitation by
377 broadening our search terms. However, we again believe our search constraints
378 produced an accurate characterisation of the EPOC literature, without creating an
379 unwieldy scoping dataset.

380

381

Conclusion

382 In this scoping review, we aimed to chart the location and purpose of EPOC-
383 related research. In doing so, we have outlined the many studies that have used
384 Emotiv EPOC as an EEG acquisition device. From BCI applications to experimental
385 research studies to clinical environments, the last 10 years has seen diverse
386 implementation of EPOC. Global use and a low financial barrier likely facilitate
387 research in areas of limited resources. Considering the cost of a research-grade
388 EEG system, it is not hard to imagine scientists and engineers in developing nations

389 embracing EPOC as an ideal device with which to conduct neuroscience research.
390 In addition, this device (and devices like it) may enable collection of data that would
391 be impossible with traditional EEG devices. For example, Parameshwaran and
392 Thiagarajan (131) used an EPOC in both rural and urban settings in India to
393 demonstrate differences in EEG signatures related to factors such as socioeconomic
394 status, exposure to technology, and travel experience.

395 We expect that this review will provide a useful reference for researchers who
396 may be looking for cost-effective, portable EEG solutions. We hope it may also serve
397 as an inspiration for those considering incorporating portable EEG devices into their
398 research and facilitate the conceptualisation and development of future experiments
399 and applications.

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406 **S1 PRISMA-ScR Checklist.**

407 **S2 Appendix. Scoping review charted data.**

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1988 58509-3.

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Brain-computer
Interface
(n = 277)

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(n = 11)

Signal
Processing
(n = 12)

Experimental
Research
(n = 51)

Validation
(n = 31)

Figure 1

Publication type █ Conference █ Journal

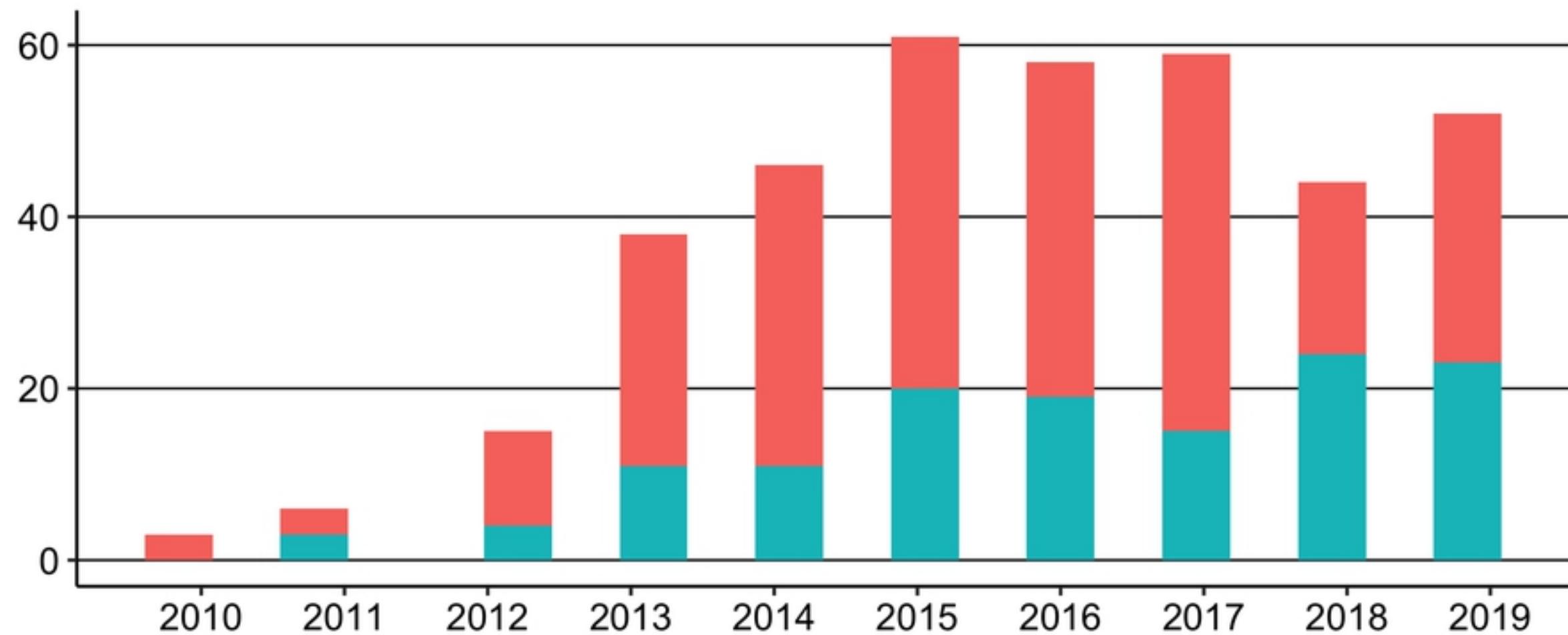


Figure 2

Category BCI Clinical Signal Processing Experimental Research Validation

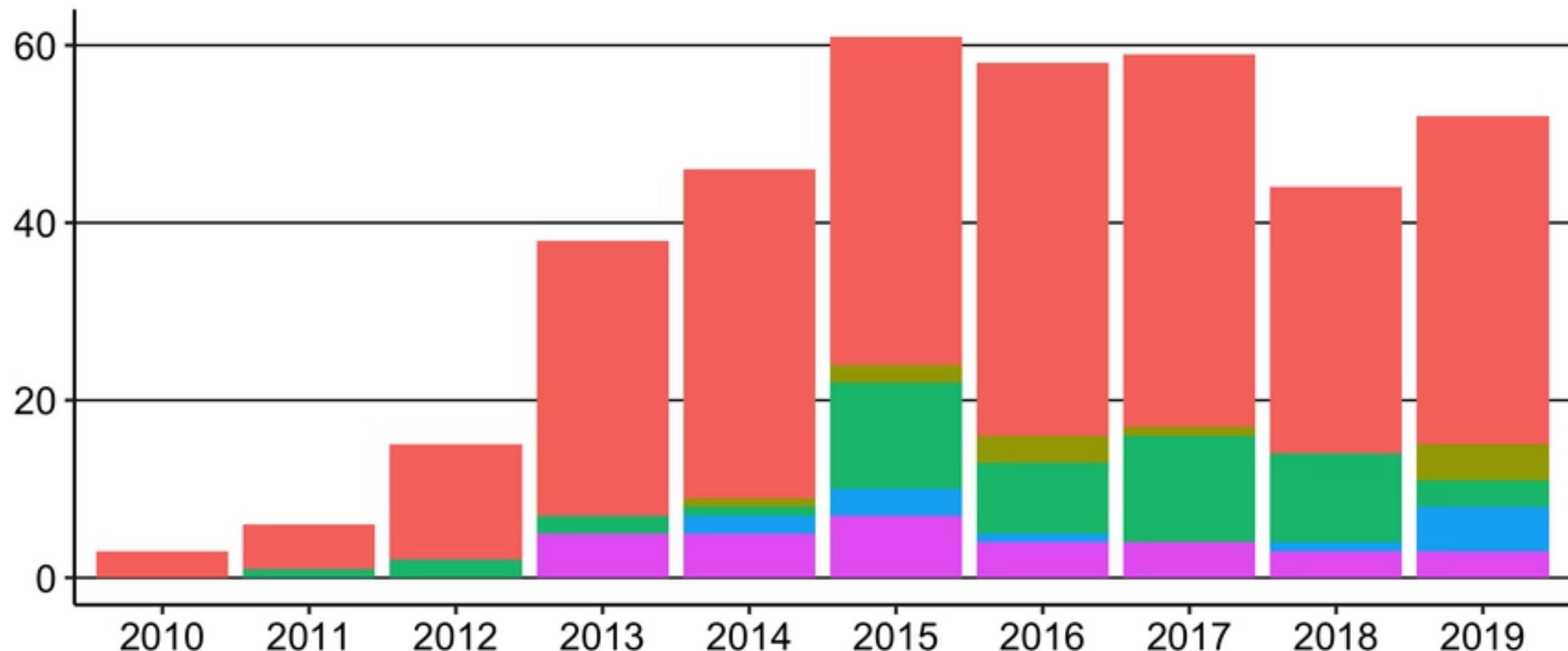


Figure 3

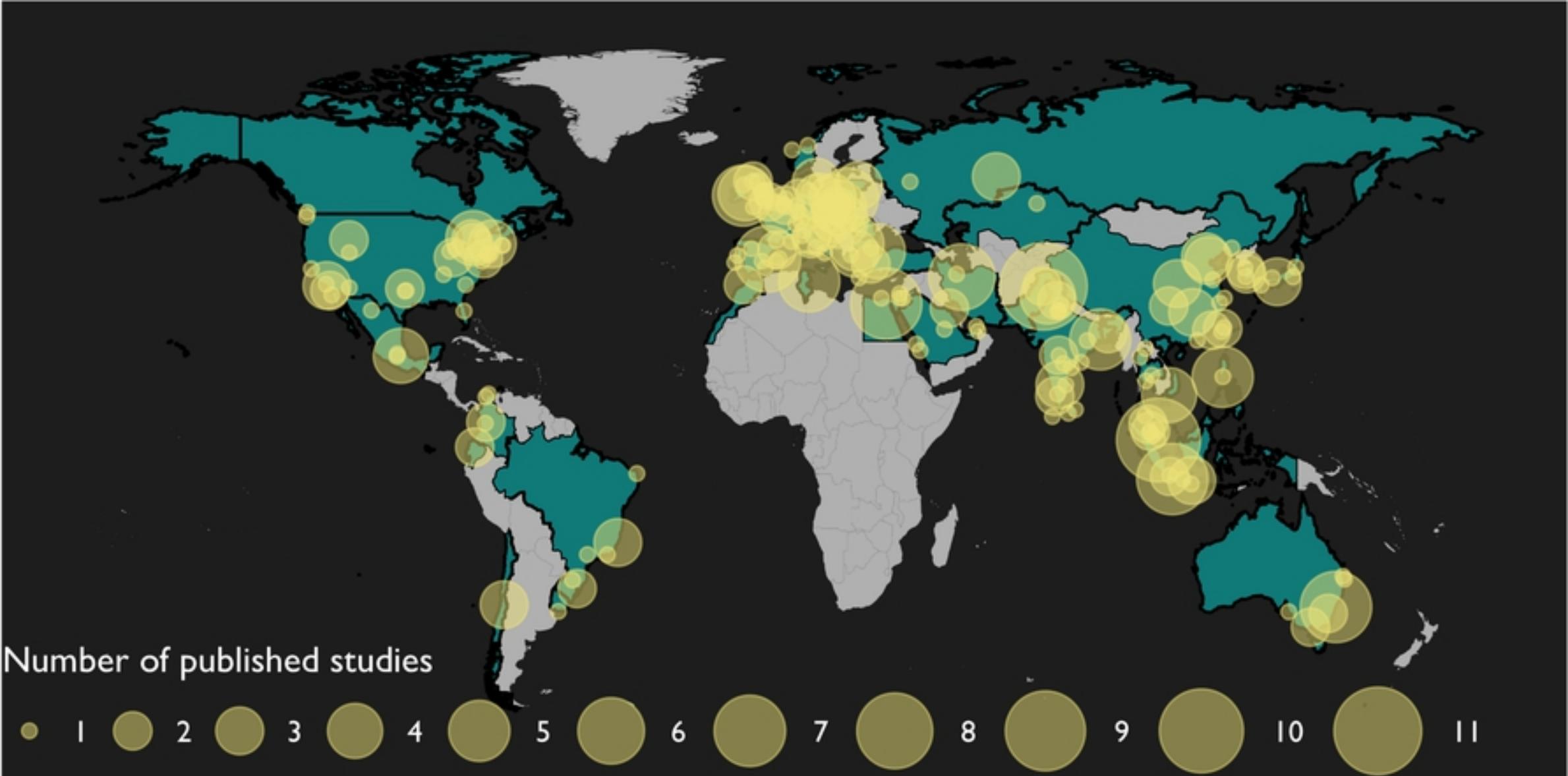


Figure 4