The effect of visual interventions on illness beliefs and medication adherence for chronic conditions: a scoping review of the literature and mapping to behaviour change techniques (BCTs)

Abstract

Background
Maintaining health with chronic conditions often involves taking multiple medications; however, approximately 50% of patients with chronic conditions are non-adherent to medication. Patients' illness beliefs inform health behaviour, including medication-taking. Research has shown that visuals accompanying health information increased patient comprehension and the accuracy of illness perceptions. To date, the influence of visuals on illness beliefs and medication adherence has not been comprehensively reviewed.

Objectives
The review aimed to collate available literature on visualisation interventions for illness beliefs and medication adherence in chronic conditions and identify key intervention characteristics.

Methods
A scoping review was conducted according to recommended guidelines and the PRISMA-ScR statement. Searches used keywords relating to 'illness', 'visual', 'adherence', 'illness perception', 'intervention', and 'medication'. Six databases were searched from inception to 2019; reference-list searching provided additional articles. Articles were included if the study population had a chronic health condition, the intervention included a visual element, had a measure of illness beliefs or medication adherence. Data regarding intervention characteristics and outcomes were extracted. Behaviour change techniques (BCTs) were identified to provide further insight into intervention characteristics.

Results
Initially, 18,012 articles were identified. Screening led to 293 full-text articles, ultimately resulting in 45 studies for final analysis. Forty-four were quantitative studies, 1 was qualitative. Studies were grouped into those using visuals to conceptualise a condition, medication reminders and educational interventions. Almost two-thirds of visual interventions were effective post-intervention, 3 sustained post-1-year, although many studies only assessed impact immediately post-intervention. BCTs from '*Natural consequences*', '*Social support*' and '*Feedback and monitoring*' categories were prevalent in effective interventions for both outcomes, particularly the '*Salience of consequences*' BCT.

Conclusions
This comprehensive scoping review found that visual interventions can positively influence illness beliefs and medication adherence. These findings highlight the need to further evaluate the impact and sustainability of visual interventions.

Keywords: visual interventions, medication adherence, illness beliefs, chronic conditions, scoping review, behaviour change techniques (BCT)

Introduction

Many chronic health conditions involve the patient managing multiple medications or lifestyle modifications to maintain or improve their ongoing health. To support self-care, healthcare providers often need to disseminate complex information about a disease or its management.

Medication adherence (hereafter adherence) is described as the extent to which a person's medication-taking behaviour corresponds with agreed recommendations from a healthcare provider[1]. It has been further explained as comprising three phases i.e., initiation, implementation, and discontinuation, with the time between implementation and discontinuation described as persistence[2]. A 2003 World Health Organisation report highlighted that approximately 50% of patients with chronic conditions are non-adherent to medication[3]. More recent studies indicate that non-adherence in chronic conditions continues at a similar rate[4–6].

Illness beliefs influence health-related behaviour, a concept that forms the cornerstone of the discipline of health psychology[7]. Leventhal's Common-Sense Model of Self-Regulation (CSM) suggests that there are five dimensions of illness beliefs: identity, cause, timeline, consequences, and cure/controllability. These factors influence both how we perceive the illness and the resulting health-related behaviour, such as medication adherence[8,9]. Building on this model, Horne *et al* demonstrated that a strong belief in treatment necessity was a key determinant for high medication adherence[10]. Proposed updates to Leventhal's original CSM acknowledge the influence of treatment beliefs on health-related behaviour[11].

The use of visuals is one method to help improve understanding of complex health information and influence treatment beliefs. A visual is described as a picture, piece of film or a display used to accompany or illustrate something[12]. Research has shown that illustrations accompanying written text or spoken word increased attention to and comprehension of a health message and subsequent recall[13]. Moreover, the use of visual images is not limited to information in the form of illustrations. A Cochrane review concluded that viewing of medical imaging scans by the patient during a consultation had the potential to positively influence their behaviour, particularly in clinical populations[14]. Furthermore, incorporating medical images in health information has been shown to improve understanding and visual appeal[15]. Active visualisation, where dynamic images or visuals are used to represent the internal process of an illness, has also been shown to provide a platform for patients to conceptualise complex abstract medical conditions[16] and improve the accuracy of illness perceptions[17].

Previous systematic reviews have explored the use of visual methods to impart information in healthcare[18–20]. For example, Stellamans and colleagues reviewed the use of computer-supported graphs to visualise risk[18], whereas Backonja et al reviewed the use of visuals in the provision of health information to an elderly population[19]. These reviews demonstrated the potential for using visuals for clarifying instructions or providing information about health status. The literature regarding the effects of visualisation on behavioural change and medication adherence has been studied in only one systematic review, limited to coronary artery screening[20]. To date, there has been no comprehensive literature review collating

95　information on the use of visual methods within interventions that target medication
96　adherence or illness beliefs, nor identifying common features of visual interventions. This
97　review explores the use of visuals within medication-related interventions to address this
98　gap in existing knowledge.
99
100　A scoping review methodology was used for the exploration of the use of visualisation in
101　healthcare since the topic is broadly defined. Moreover, the definition of visualisation is not
102　limited to any one modality or intervention type and as such an overview would be
103　enhanced by the inclusion of all study types. Conducting a scoping review using transparent
104　reporting and replicable methods with predefined inclusion and exclusion criteria ensures
105　rigour. In addition, the iterative nature of a scoping review is of benefit where the full extent
106　of the literature is unknown[21].
107
108　Identification of the Behaviour Change Techniques (BCTs) within each intervention (also
109　known as coding or mapping) was used to provide further insight into the mode/s of action
110　of the intervention. Behaviour change techniques are defined as '*an observable, replicable*
111　*and irreducible component of an intervention designed to alter or redirect causal processes*
112　*that regulate behaviour; that is, a technique is proposed to be an 'active ingredient''*[22]. It has
113　been noted that the descriptions of both interventions as a whole and their component
114　parts are often poorly described or reported using disparate terminology[23,24]. The Behaviour
115　Change Technique Taxonomy v1 was created as a common language with which to describe
116　components of an intervention using standard definitions[22]. Identifying BCTs within an
117　intervention using standardised descriptions of each component enables exploration of
118　interventions at the more granular level of 'active ingredient' and facilitates further
119　comparison between interventions.
120
121　**Aim**
122
123　This review aimed to collate and summarise the available data regarding the use of
124　visualisation interventions to influence illness beliefs and medication adherence in
125　populations with chronic health conditions, to explore their effects and identify key
126　intervention characteristics.
127
128　**Method**
129
130　This scoping review was conducted according to the recommended guidelines[25–27] and the
131　Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping
132　reviews (PRISMA-ScR)[28]. As is considered best practice, a protocol was written *a priori* and
133　only deviated from where it was deemed necessary (See Supplementary Material).
134
135　*Eligibility criteria*
136　Initial inclusion and exclusion criteria were determined following the 'Participants, Concept,
137　Context and Types of Evidence' structure, while also considering the PICOS framework
138　(Population, Intervention, Comparator, Outcome, Study design) as a guide to manage the
139　potential wealth of information.

Participants: Adults 18 years old or over who have been diagnosed with a chronic health condition were included. Studies where the intervention was aimed at a caregiver or where the patient was looked after in a care home or hospital setting were excluded.

Concept: The visual element of the study formed the core concept explored in this scoping review. Visuals included, but were not limited to pictures, animation, 3-D models, smart-phone based applications (apps). Films or animations with integral narration were not included, however film or animation-based interventions that included narration by a facilitator or short captions were eligible for inclusion, as the captions or facilitator role were considered to provide clarification of understanding while permitting an element of personal interpretation of the visual. Studies showing any interventions with a primary or secondary aim of improving adherence to medication and/or exploring illness beliefs were included. The intervention group could be compared to usual care, an alternative treatment strategy or within the study group i.e., pre- and post-intervention. Included studies contained baseline and future time-point data. Any measures of illness or medication-related beliefs and/or medication adherence were eligible for inclusion. Studies where quality of life was the sole outcome measure for illness beliefs were excluded, as were studies where the adherence measure was solely based on a physical parameter that can be influenced by lifestyle changes e.g., HbA1c.

Context: There was no restriction on publication date or geographical location, however studies where no English translation was available were excluded.

Types of evidence sources: Studies were of any experimental design.

The criteria were revisited once the range of study types was understood, as is permissible in scoping review methodology[25] and amendments made on two occasions. The first amendment was at initial screening stage to include participants of all ages, since the exclusion of children would have omitted certain intervention types more commonly directed at children, for example those that used visuals as part of a computer game. The purpose of the scoping review was to provide a broad overview of the literature; therefore, this protocol amendment was justified. Studies where the sole visual element was a graphical representation of numerical data were excluded at this point, as this was considered a distinct field of data visualisation. At full-text screening stage, studies that were based around avatars were excluded due to their use of the visual as a surrogate for a human in a consultation scenario, rather than as a method of illustrating a concept. See Supplementary Material for amendments to protocol.

Search strategy

Six electronic databases were searched in January 2019: Embase, Medline, PsychINFO, Proquest, Scopus and the Cochrane Library. Additionally, reference lists of relevant papers were hand searched. Stakeholders were not used as an additional data source. Keywords were determined under six headings: illness, visual, adherence, illness perception, intervention, medication (Table 1). MeSH terms were not used due to lack of specificity, given the broad nature of the search strategy[29]. Full search strategies are presented in the supplementary material.

Insert Table 1 here

187 Electronic database searches were undertaken by one reviewer (SLB) in January 2019.
188 EndNote™ bibliographic software (version X9) was used to organise search results.
189 Duplicates were removed using Endnote™ and the remaining articles exported to the
190 Rayyan Qatar Computing Research Institute (QCRI) screening tool[30]. Articles were first
191 screened by title and abstract using the *a priori* inclusion and exclusion criteria, with
192 additional studies included after amending the criteria to include participants of all ages.
193
194 In the second screening phase, full text of included studies was evaluated for eligibility. If no
195 full-text existed, for example a conference abstract with no related full-text publication, the
196 article was excluded. Where the nature of the visual element in the study was unclear,
197 additional details were sought from the study authors. If no further details could be
198 obtained, the article was excluded. Where multiple publications related to the same study,
199 only the publication which described the intervention with the most relevance to the
200 scoping review aim was included. Ten percent of full text articles were screened by a second
201 reviewer (DHJ). Results were compared and inconsistencies resolved by discussion. Had
202 reviewers (SLB, DHJ) not reached agreement during this discussion, a third independent
203 reviewer would have been sought; however, this was not found to be necessary.
204
205 Information was recorded for sample characteristics using a purpose-designed data
206 extraction form. Information was recorded for the following sample characteristics: study
207 population description, number of participants, study country and setting, and chronic
208 condition studied. Details of the intervention included: the intervention type (for example,
209 medication reminder chart, computer game, educational pamphlet), intervention facilitator,
210 language provision and a brief intervention overview. Outcome measures were noted,
211 including measures of illness belief and/or adherence. Study outcomes, including statistical
212 significance where reported, were captured. Data were extracted by one reviewer (SLB) and
213 a sample of cases discussed with a second reviewer (DHJ). These cases were chosen at
214 random to check agreement regarding inclusion or the detail of the characteristics recorded.
215 Additional studies were discussed where questions remained regarding the suitability for
216 inclusion or how to describe or group the intervention. In all cases, the conclusion on how
217 to proceed unanimously supported the initial decision of the first reviewer. Had there been
218 failure to agree, a third reviewer would have been sought to resolve differences. In this
219 case, a second random sample of studies would also have been discussed to ensure ongoing
220 agreement.
221
222 *Evaluation of included studies*
223 The study aim was to provide an overview of the effects of visualisation studies and identify
224 commonalities between intervention types and their components. The intention was not to
225 synthesize the best available evidence to determine the most effective intervention, and
226 therefore a risk of bias analysis was not deemed necessary. However, all studies were
227 evaluated for quality of intervention reporting using a version of the TIDieR checklist
228 modified for the evaluation of trials[23].
229
230 *Behaviour Change Technique coding*
231 One of the scoping review aims was to explore key characteristics within visual
232 interventions. Describing the interventions in terms of their behaviour change techniques
233 provided a method of reporting the intervention components using definitions that were

234 well documented in the literature. Using standardised terminology to describe BCTs
235 facilitates comparison between interventions; therefore, the BCTs coded were those
236 defined by the Behaviour Change Techniques Taxonomy v1[22]. This taxonomy is a structured
237 list of 93 BCTs with accompanying definitions, grouped into 16 categories. The coding
238 method was adapted from that of Presseau et al[31], incorporating best practice
239 recommendations from the BCT taxonomy v1 training[32], illustrated in Figure 1.
240
241 Insert Figure 1 here
242
243
244 *'First round' coding*
245 Interventions were coded independently by two researchers (SLB, ES). Both coders had
246 completed the BCT Taxonomy V1 online training and were participants in monthly BCT
247 coding group workshops.
248 ***Identifying the target population and behaviour***. The target population was identified as
249 participants in the visual-based intervention. BCTs identified in control groups or study arms
250 without visual interventions were not coded. The target behaviour was identified as
251 medication adherence or self-management of a health condition. Only BCTs that related to
252 the target population and behaviour were recorded.
253 ***Identifying coding source material.*** Original papers and published supplementary material
254 were used as primary source material. Where it was indicated that an intervention was
255 described in detail in a previously published paper or protocol, this was used as additional
256 resource. Where interventions such as websites, videos or computer games were available
257 to view online, these were also used as coding source material.
258 ***Independent coding.*** The BCT taxonomy v1 definitions were used as the basis for the
259 coding, with all 93 BCTs considered. The whole paper was reviewed, initially focussing on
260 the results section or where the intervention was described in most detail. The paper was
261 then re-read to identify any further BCTs, along with any supplementary coding sources.
262 BCTs were coded as present or absent; where BCTs were operationalised in multiple ways
263 within an intervention the BCT was only coded once. As the visual element was often
264 embedded within a complex intervention, BCTs were coded for the whole intervention.
265
266 *'Second round' coding*
267 A collaborative coding exercise was then undertaken with the same two coders (SLB, ES).
268 First round coding results were shared. Decisions were made as to whether each identified
269 BCT should be accepted into the final coding list. For inclusion, agreement from both coders
270 was necessary. Four scenarios presented themselves as illustrated in Figure 1.
271
272 *Analysis and presentation of results*
273 Results of the scoping review and BCT coding (mapping) are presented both in summary
274 tables and as a narrative description. For further synthesis of the data, studies were
275 grouped according to three broad categories: those that used visuals 1) to help participants
276 conceptualise a condition (conceptualisation interventions), 2) within an educational
277 intervention and 3) as part of a medication reminder system. As is common in scoping
278 reviews, due to the diverse nature of the studies and intervention types, no statistical meta-
279 analysis was undertaken.
280

281   Due to the inclusion of both adequately powered trials and pilot studies where numbers
282   may have been too small to determine statistical significance, outcomes are referred to as
283   being effective or non-effective. For the purpose of analysis, interventions were considered
284   effective if the main study group or a sub-group analysis showed improvement or statistical
285   significance (where calculated) over the control group for any outcome measure, or
286   improvement post intervention if no control group was used. Statistical significance was
287   referred to where possible; $p < 0.05$ denoted statistical significance.
288
289
290   **Results**
291
292   Database searches returned 24,835 articles, leaving 18,023 articles for title and abstract
293   screening after duplicates were removed. Hand searching provided a further 11 articles. Full
294   text of 293 articles was screened; 52 studies were included at this stage. After discussion 7
295   of these 52 articles were excluded, leaving 45 studies in the final analysis (Figure 2).
296
297   Insert Figure 2 here
298
299
300   One study used qualitative methodology, the remaining 44 were quantitative in nature. Of
301   these, 31 were randomised controlled trials (RCT), 12 had a pre-post design and 1 was a
302   crossover design where both study groups experienced the intervention. Nine of the
303   included studies were described as pilot studies.
304
305   Most of the studies were conducted in the United States of America (USA) (n=23). The
306   remainder were situated in Australia (n=5), New Zealand (n=4), Spain (n=2), South Africa
307   (n=2), United Kingdom (UK) (n=2), Kurdistan (n=1), Iran (n=1), Canada (n=1), Israel (n=1),
308   Denmark (n=1), Sweden (n=1) Germany (n=1), Netherlands (n=1) and Thailand (n=1). Only
309   one study [33] took place in more than one country: USA, Canada, and Australia. The earliest
310   study took place in 1997, the most recent in 2019. The studies ranged from four
311   participants[34] to 3532 participants in the largest study[35]. Ten studies were aimed at children
312   and young adults (age range 1 month to 29 years old). Two studies recruited women
313   only[36,37].
314
315   Six of the 45 studies identified investigated more than one condition; only one of these
316   specifically recruited participants with multiple comorbid conditions[38]. Fourteen of the
317   studies recruited patients with cardiovascular disease, 8 studies looked at participants with
318   HIV, 7 studied a diabetes cohort, 4 arthritis (2 juvenile idiopathic arthritis, 2 rheumatoid or
319   psoriatic arthritis in an adult population). Three studies focussed on asthma, 3 osteoporosis,
320   2 renal disease, 1 sickle cell disease, 1 cancer, 1 epilepsy, 1 Parkinson's disease and 1
321   schizophrenia. One study recruited general medicine in-patients and 3 included participants
322   with any chronic disease.
323
324   The intervention types were diverse, however there were some commonalities with the
325   visual elements of the intervention. The most common visual element comprised an
326   illustrated medication schedule, with icons or photographs to represent each medication in
327   a regimen (n=12). Paper-based pictorial educational material was included in 7 studies:

digital pictorial educational material in 5 studies. Two studies used a picture book. Six studies included animated models or pictures delivered digitally. Five studies utilised computer games. Seven studies used medical scan pictures and 5 incorporated a 3-dimensional (3-D) model.

Of the 45 studies, 39 had medication adherence as an outcome and 20 explored illness beliefs. Fourteen studies measured both outcomes. Table 2 provides a summary of the study characteristics.

Insert Table 2 here

Medication adherence measures

A variety of different adherence measures were used to assess medication adherence. Fifteen studies used 1 measure to capture adherence, the remaining 24 used 2 or more. Twelve different patient self-report measures were used. The most utilised self-report measure was the Morisky Medication Adherence Scale (MMAS), with 3 studies using the 4-item version[39] and 7 studies using the updated 8-item version[40]. Seven other validated questionnaires were used; 6 studies used an unspecified self-report questionnaire or measured adherence with single questionnaire items. Four studies required patients to self-report adherence via the digital device used to deliver the intervention and 1 study used a patient diary. One study used interview questions to determine adherence. Twelve studies used pharmacy refill data, however there was variation in how the data were used to calculate adherence. Four studies calculated the Medication Possession Ratio, 2 studies calculated the Cumulative Medication Gap, and 1 calculated the Proportion of Days Covered. Five studies did not specify how pharmacy data was used to calculate adherence. Five studies used pill counts to measure adherence and 4 used an electronic Medication Event Monitoring System (MEMS). Of the 39 studies using multiple measures of adherence, 3 did not report results from all measures [38,41,42]. Only 12 of the remaining 21 studies found all adherence measures demonstrated the same result.

Illness and medication-related beliefs measures

Studies varied widely in how they explored illness beliefs. Nine studies measured patient self-efficacy. Five focused on self-efficacy for medication use, with 4 of these using the Self-efficacy for Appropriate Medication Use (SEAMS) questionnaire as the outcome measure [43]. Two studies measured self-efficacy for specific disease states. One used the short self-efficacy assessment, and 1 did not specify how self-efficacy was measured. Two studies used the Patient Activation Measure (PAM) [44], measuring patient knowledge and confidence to manage their health. Three studies captured patient motivation; of these, 2 measured motivation to take medication and 1 measured motivation to improve diabetes management. One study used the Multidimensional Health Locus of Control (MHLOC) Scale[45] and 1 used a questionnaire based on the Theory of Planned Behaviour[46]. The Brief Illness Perceptions Questionnaire (Brief-IPQ)[47] was used in 6 studies. One study measured perceived seriousness of diagnosis and patient risk perceptions. Three studies used the Beliefs about Medication Questionnaire (BMQ)[10], 1 used the BMQ-Specific subscale only and a further 3 studies used selected questionnaire items from the BMQ-Specific. One study used the Barriers to Adherence Tool (BAT)[48] and 1 the Brief Medication

Questionnaire[49]. One study conducted in a diabetes population also measured diabetes self-care[50] and diabetes distress[51]. The one qualitative study measured participants' beliefs through open-ended interview questions only. Full details of medication adherence and illness beliefs outcomes are presented in the Supplementary Material.

Evaluation of the quality of intervention reporting
Studies varied in their reporting, some describing the intervention fully and others providing scant detail. Evaluation using the TIDieR checklist for intervention reporting found that most papers described the materials needed in the intervention well but were poor at describing the procedures followed. Many papers did not adequately describe the qualifications of the intervention facilitator (where applicable) or details of facilitator training. Most studies did not attempt to measure intervention fidelity; therefore, it was not possible to determine if the intervention had been delivered as intended. Details of the TIDieR checklist evaluation can be found in the supplementary material.

Findings by intervention category

For further analysis the qualitative study was considered separately from the quantitative studies, rather than quantizing and synthesizing the qualitative data as in a mixed methods systematic review, in keeping with the scoping review methodology[52]. This resulted in 44 quantitative studies being investigated for further analysis, which were grouped according to the 3 intervention categories previously described: 1) conceptualisation interventions, 2) educational interventions and 3) medication reminders. The one qualitative study used visual methods to conceptualise a condition[53]. Two studies incorporated elements of more than one category [54,55]; these are therefore discussed within both relevant categories.

1) Conceptualisation interventions

Insert Table 3 here

Fifteen studies measuring medication adherence used visuals to enable participants to conceptualise a condition or illness. Six showed participants their medical scan pictures, 4 showed animated illustrations on an electronic device, one used 2-dimensional illustrations and 4 were 3-D models. Ten conceptualisation studies explored illness beliefs.

Fourteen of the studies were quantitative. Nine out of the 14 quantitative conceptualisation interventions measuring adherence showed positive outcomes. Seven showed statistically significant improvement [35,53,56–61]; 1 showed positive results in a sample too small to be statistically analysed [34]. Mols and colleagues[62] demonstrated improvement for a sub-group analysis. Seven of 10 quantitative conceptualisation interventions which measured illness beliefs showed positive outcomes[36,57,61,63–66].

Six of the 9 effective quantitative interventions collected adherence data for a follow-up period post-intervention. In 5 of the 6 studies[35,56,58,59,61], the positive effect was sustained for the follow-up period. Follow-up periods ranged from 2 months to 4 years, with 3 of the 5 studies showing improved adherence for longer than 1 year. Two of the 3 showed personal

422   cardiovascular scan information to participants[56,59] and one used a 3-D model to
423   demonstrate the effects of adherence on HIV viral load[58]. For illness beliefs outcomes, 5 of
424   the 7 effective studies collected data for a follow-up period ranging from 10 days to 3
425   months post-intervention. Three of the 5 studies continued to show effective outcomes at
426   follow-up[61,64,66].
427
428   Most effective conceptualisation interventions were facilitated by an individual as part of
429   their delivery. The type of facilitator varied between studies: most were healthcare
430   professionals or researchers, but one study trained community health workers to deliver the
431   intervention[61]. Six of the 7 effective studies measuring illness beliefs included a facilitated
432   intervention. A smartphone app was the only self-directed intervention to positively
433   influence illness beliefs [57]. This was echoed in adherence studies, with 6 of the 9 effective
434   studies being facilitated. Studies with multifaceted interventions [Footnote 1] were more
435   effective at improving adherence outcomes. Five out of the 9 effective studies contained
436   additional adherence strategies, also incorporating motivational counselling [61,62], brief
437   information on potentially beneficial lifestyle changes [35], a medication reminder clock and
438   graphical representation of current plasma concentrations of medication [34,57]. For illness
439   beliefs outcomes, most effective interventions were single component (6/7 studies). In most
440   effective conceptualisation interventions, the participant had only one interaction with the
441   intervention. In 6 of the 9 effective adherence studies, the participants viewed the visuals in
442   a single session. This was also the case for effective studies measuring illness belief
443   outcomes, where 6 of 7 effective interventions were accessed in a single session.
444
445   Five of the 14 quantitative conceptualisation studies measuring adherence were non-
446   effective. These interventions comprised of medical scans (n=2), digital animations (n=2)
447   and one 3-D model. In 4 of the 5 non-effective adherence studies, the visual intervention
448   was single component. All 4 interventions were facilitated and accessed once [63–65,67]. Shah
449   and colleagues[55] had the only multifaceted intervention; this was also the only intervention
450   of the 5 to be self-directed and to be accessed on several occasions. In the 3 non-effective
451   conceptualisation interventions exploring illness beliefs, all were multifaceted, facilitated
452   interventions, delivered in a single session.
453
454   The one qualitative study used 3-D models to help participants conceptualise an illness. This
455   intervention was facilitated, with the participants being informed about inflammatory joint
456   disease and provided with a model of a healthy joint and an erosive joint to hold and
457   compare. The participants interacted with the models on one occasion, after which

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[Footnote 1] Interventions that contain several interacting components are referred to in this review as
multifaceted interventions. Multifaceted interventions could also be considered 'complex' or
'multicomponent' interventions, terms that are often used interchangeably in the literature and not clearly
defined [101]. The criteria for a multifaceted intervention has been based on the definition of complex
interventions by the Medical Research Council [102] and Cantera et al [101], where a complex intervention was
described as an intervention with at least two interacting components. In this review, the mode of delivery
may be the same for all facets of the intervention, for example educational information and a reminder alarm
being delivered through the same smartphone app. Conversely, the modes of delivery may be different,
although forming part of the same intervention; for example, where participants have educational counselling
sessions and are also provided with a medication reminder. The visual element may be present in one or more
of the facets of the intervention. Interventions that contain only one component are referred to as single
component.

458 outcomes were explored through semi-structured interviews. Most participants articulated
459 that the intervention would improve adherence, particularly if viewing models of their own
460 joints.
461
462 Table 3 provides detail for conceptualisation interventions with corresponding BCT coding.
463
464 *2) Educational interventions*
465
466 Insert Table 4 here
467
468
469 Fourteen studies measuring adherence incorporated visuals into an educational
470 intervention. Nine of the 14 educational interventions were aimed at children and young
471 adults. Nine of the 14 were found to be effective with 7 studies showing statistically
472 significant improvements in medication adherence[33,68–73]. A further 2 studies showed
473 statistically significant improvements in a sub-group of participants[74,75]. Four of the 7
474 educational interventions measuring illness beliefs showed statistically significant
475 improvements in medication adherence.
476
477 Four of the 9 educational interventions showing effective adherence outcomes collected
478 data for a follow-up period ranging from 3 weeks to 3 months post-intervention [69,70,72,73]. All
479 4 continued to show positive effects at the end of this follow-up period. Only one
480 intervention measured illness beliefs outcomes for a post-intervention period[70]; the positive
481 effects on illness beliefs were not sustained during this 3-week follow-up period.
482
483 Most of the effective educational interventions were self-directed (5/9 measuring
484 adherence, 3/4 measuring illness beliefs). Where interventions were facilitated, the person
485 providing facilitation was not always a specialist in the area, and therefore this was not
486 necessary for an effective outcome. For example, a lay member of the community trained as
487 a 'community health worker' or a nurse without expertise in the study condition were used
488 as facilitators. In most of the effective educational interventions, the educational content
489 was the sole intervention component. Six of the 9 effective adherence interventions were
490 single component, as were 3 of the 4 effective illness belief interventions. Most effective
491 educational interventions exposed the participant to the intervention on multiple occasions.
492 This was found for 8 of the 9 effective adherence interventions and 3 of the 4 effective
493 illness belief interventions.
494
495 Five out of the 14 studies did not demonstrate any statistically significant improvements in
496 medication adherence [37,55,76–78]. Three of the 5 non-effective studies were single-component
497 interventions, whereas 2 were multi-faceted. Two interventions were used in a single
498 session, 3 studies included interventions which were accessed multiple times. Three
499 interventions were facilitated and 2 were self-directed. Three of the 11 educational
500 intervention measuring illness beliefs were non-effective. Two of these were self-directed
501 interventions and 1 was facilitated. Only 1 non-effective intervention was multi-faceted. All
502 non-effective illness belief interventions were accessed on more than one occasion.
503
504 Table 4 provides detail for educational interventions with corresponding BCT coding.

507 *3) Medication reminder interventions*

508

509 Insert Table 5 here

510

511 Twelve studies incorporated illustrated medication reminders. Two were delivered via a
512 smartphone app [79,80], 1 was accessed via a digital tablet [81] whilst the remainder were paper-
513 based medication schedules.

514

515 Six of the 12 studies reported statistically significant adherence outcomes [79–84]. Of the 2
516 studies reporting illness belief outcomes, 1 was effective [80]. Five out of the 6 effective
517 studies contained multifaceted interventions, also providing educational or social support.

518

519 Only 1 of the effective studies collected adherence data for a post-intervention follow-up
520 period[84], however the positive effects seen at 9 months were not sustained by 1 year. None
521 of the medication reminder studies measuring illness belief effects collected data for a
522 follow-up period.

523

524 Three of the 6 non-effective studies used the medication schedules alone [38,85,86]. Only 1 of
525 these 6 provided any additional ongoing support from a healthcare professional beyond the
526 dispensing of the medication and supply of the medication schedule by a pharmacist [76].

527

528 Table 5 provides detail for medication reminder interventions with corresponding BCT
529 coding.

530

531 **Findings of BCT mapping/coding**

532

533 BCTs were independently coded for all 44 studies, with 205 BCTs identified overall. Of these,
534 42% (86/205) were identified by both coders independently. The remaining.58% (119/205)
535 of BCTs were initially identified by only one coder, mainly due to the variation in the
536 language used to describe the interventions and the location of the descriptions within each
537 article. For example, elements of the intervention could be presented in the introduction,
538 methods, results, or supplementary material, making it challenging to identify all BCTs on
539 first review. Once the initial coding was shared and discussed, 82 of the 119 codes identified
540 by only one coder were accepted by both and 24/119 were rejected, as the supporting
541 evidence was not considered strong enough to justify inclusion. Thirteen instances
542 remained where the coders could not agree on a coding decision, all concerning BCT *12.5*
543 *Adding objects to the environment*. After advice from an expert (LA) (see
544 acknowledgements) regarding the interpretation of the BCT definition, none of these
545 instances were included in the final coding. The final coding list therefore contained 168
546 BCTs. The BCT coding strategy providing detail of the interpretation of BCT definitions with
547 reference to the included studies is provided in the supplementary material.

548

549 BCTs were coded from 15 of the 16 BCT Taxonomy V1 categories. BCTs within the category
550 '*Natural consequences'* were coded most frequently (n=43), followed by '*Feedback and*

551 *monitoring*' (n=24), '*Shaping knowledge*' (n=18) '*Comparison of outcomes*' (n=18) and
552 '*Social support*' (n=18). There were no BCTs coded within the category '*Self-belief*'.
553
554 All interventions included across the 45 studies could be coded to 32 individual BCTs,
555 equating to 34% of the 93 BCTs in the BCT Taxonomy v1. The mean number of BCTs coded
556 per intervention was 3.82 (range 0-10). The most frequently coded BCTs were *5.1*
557 *Information about health consequences* (n=23), *4.1 Instruction on how to perform a*
558 *behaviour* (n=18), *5.2 Salience of consequences* (n=16), *7.1 Prompts and cues* (n=15) and *3.1*
559 *Social support (unspecified)* (n=14).
560
561 Figure 3 shows the BCTs coded for effective and non-effective quantitative studies which
562 included medication adherence as an outcome. Only one BCT was coded for the qualitative
563 study, BCT *5.2 Salience of consequences*.
564
565
566 Insert Figure 3 here
567
568
569 Interventions in studies that measured adherence outcomes were mapped to 30 of the 93
570 BCTs (32% of BCTs in the BCT taxonomy v1). The most frequently coded BCTs were *5.1*
571 *Information about health consequences* (n=19), *4.1 Instruction on how to perform the*
572 *behaviour* (n=16), *5.2 Salience of consequences* (n=14), *7.1 Prompts/cues* (n=13), *3.1 Social*
573 *support (unspecified)* (n=10) and *9.1 Credible source* (n=10). The mean number of individual
574 BCTs coded per intervention was 3.76 (range 0-9) for effective studies and 3.07 (range 1-7)
575 for non-effective studies.
576
577 For the 9 effective quantitative interventions (5 conceptualisation and 4 educational) that
578 sustained a positive effect on adherence outcomes at post-intervention follow-up, the most
579 frequently coded BCTs were *5.1 Information about health consequences* (n=6), *5.2 Salience*
580 *of consequences* (n=6), *9.1 Credible source* (n=4) and *2.6 Biofeedback* (n=3). BCTs *5.1*
581 *Information about health consequences* and *5.2 Salience of consequences* were common to
582 all 3 studies showing improved adherence for a follow-up period greater than 1 year, with
583 *2.6 Biofeedback* also being coded in 2 of the 3 studies. Please refer to Supplementary
584 Material for further information showing the coding frequency for individual BCTs.
585
586 BCTs coded for effective and non-effective quantitative studies for illness beliefs outcomes
587 are presented in Figure 4.
588
589 Insert Figure 4 here.
590
591
592 Twenty-nine individual BCTs were coded in studies measuring illness beliefs (31% of BCTs
593 available). The most frequently coded BCT was *5.1 Information about health consequences*
594 (n=13), followed by *5.2 Salience of consequences* (n=11) and *3.1 Social support (unspecified)*
595 (n=6). When comparing effective and non-effective studies, the mean number of BCTs
596 coded for effective studies was 3.83 (range 1-10) and 4.43 for non-effective studies (range
597 1-9). For the 3 interventions measuring illness beliefs where the positive effect persisted for

598   the follow-up period, the most frequently coded BCTs were *5.1 Information about health*
599   *consequences* (n=2), *5.2 Salience of consequences* (n=2) and *2.6 Biofeedback* (n=2).
600
601   **Discussion**
602
603   This is the first review to assess the effects of visualisation interventions on influencing
604   illness beliefs and treatment adherence in populations with chronic health conditions. The
605   scoping review methodology allowed a comprehensive overview of the available literature.
606   The narrative synthesis highlighted trends within intervention categories; coding BCTs
607   provided insight into the active ingredients of interventions. Overall, this review found that
608   interventions incorporating visual elements were more often effective than not, with almost
609   two thirds of studies measuring adherence or illness beliefs having positive results. Sixty
610   four percent of both conceptualisation and educational interventions reported positive
611   outcomes, as did 50% of medication reminder interventions. Finally, this scoping review
612   results suggest the elements common to visual interventions vary between the three
613   intervention types.
614
615   Adherence interventions focused on conceptualisation or education were often single
616   component; most medication reminder interventions were multifaceted. This finding is
617   somewhat unexpected since previous research suggests that successful interventions to
618   support adherence and change illness beliefs are those with multiple facets[87,88]. However,
619   Nieuwlaat *et al* [88] suggested that while multi-faceted interventions have shown superior
620   efficacy over usual care, they are rarely directly compared to single component
621   interventions and therefore it remains unknown whether complex interventions are always
622   more effective. Similarly, when considering illness beliefs, most educational and
623   conceptualisation interventions had only one component. When exploring illness beliefs in
624   coronary heart disease, the systematic review by Goulding *et al* found that both complex
625   and simple interventions were effective[89].
626
627   Facilitated interventions were more common in conceptualisation interventions, whereas as
628   many educational interventions were self-directed as facilitated. In a systematic review,
629   Schubbe et al[90] found that in successful interventions including visuals, pictorial information
630   was accompanied by brief text. They suggested that the text provided a second learning
631   opportunity, aiding interpretation of the pictorial information. It is possible that the
632   facilitated interventions fulfilled this second learning opportunity role, with the facilitator's
633   narrative providing clarification of complex information. By their nature, educational
634   interventions have scope for explanation of pictorial elements within the educational
635   material, reducing the need for a facilitator. Research has shown that the intervention
636   facilitator can have a bearing on adherence outcomes. Conn et al (2016) found that the
637   most efficacious interventions for improving blood pressure outcomes through medication
638   adherence were provided by pharmacists [91]. This could be in part due to the healthcare
639   professional being considered a *'credible source'* of information. This review found that a
640   third of effective adherence studies incorporated a credible source of information (BCT *9.1*),
641   as did one-fifth of non-effective studies.
642
643   This review found that educational and medication reminder interventions with a visual
644   component were often provided on multiple occasions. The reverse was found for

645 conceptualisation interventions, with most of the interventions being provided in a single
646 'dose'. There is support in the literature for repeated intervention to maintain adherence. In
647 a systematic review of blood pressure outcomes of medication adherence interventions,
648 Conn et al found that studies with a larger intervention dose provided greater blood
649 pressure lowering effects [91]. Voils and colleagues suggested that when considering the
650 optimal dose of a behavioural intervention, intervention designers should consider the
651 patient burden of the intervention balanced against the dose that maximises patient benefit
652 [92]. It is notable that in this review, visual interventions designed to conceptualise a condition
653 were successfully operationalised with minimal contact time.
654
655 Most interventions targeting both adherence and illness beliefs incorporated BCTs from
656 'Natural consequences'. BCT *5.1 Information about health consequences* was the most
657 frequently coded BCT overall, found in almost two thirds of effective interventions
658 measuring illness beliefs and over half of effective interventions focussed on adherence.
659 This is perhaps unsurprising as health psychology theory identifies strong links between
660 illness beliefs and health behaviour, as explained by Leventhal's CSM. BCT *5.2 Salience of*
661 *consequences* was also coded frequently, notably identified in most of the conceptualisation
662 interventions. These results might suggest that the use of visual methods to demonstrate
663 salience of consequence could influence illness beliefs and medication adherence. The
664 impact of demonstrating salience of consequences is suggested elsewhere in the literature.
665 A study exploring visual vs text messages to encourage healthy eating found that the
666 salience of images appeared to positively influence the participant's risk evaluations and
667 subsequently impact their attitudes and intentions to engage in health behaviours [93].
668 Importantly, both *5.1 Information about health consequences* and *5.2 Salience of*
669 *consequences* were identified in interventions that had a sustained positive effect for more
670 than a year (where measured).
671
672 BCTs concerned with feedback and monitoring were a common feature of visual
673 interventions, identified in almost half of the interventions targeting adherence.
674 Furthermore, BCT *2.6 Biofeedback* was identified in 2 of the 3 studies where the effect of
675 the intervention was sustained for a follow-up period greater than a year. Van Heuckelum *et*
676 *al* [94] found that electronic monitoring feedback from electronic tablet containers had a
677 positive effect on medication adherence. This review found that although BCTs from this
678 category were often incorporated in studies targeting illness beliefs, they appeared in
679 proportionally more non-effective studies.
680
681 Social support was also found in this review to be a frequently coded BCT for both
682 adherence and illness beliefs. Zeber et al[95] found that poor social support was a barrier to
683 adherence. Sengstock et al noted that reduced social support was a factor in non-adherence
684 for older adults after coronary bypass surgery [96].
685
686 Although BCT *4.1 Instruction on how to perform the behaviour* was frequently identified in
687 interventions measuring adherence outcomes; this BCT was incorporated in equal numbers
688 of effective and non-effective studies.
689
690 **Strengths and limitations**
691

692 This scoping review was conducted in a systematic manner according to the guidelines,
693 maximising rigour and minimising the likelihood of a relevant article being excluded.
694 Additionally, a percentage of results were checked by a second reviewer for accuracy.
695 However, there are some limitations to this scoping review which mean the results must be
696 interpreted with caution. Only ten percent of full-text articles were screened by two
697 reviewers, which may have influenced the articles that remained for analysis. However,
698 standard criteria for inclusion and exclusion were used and agreement between reviewers
699 was high for the percentage of articles that were screened by both. Like all scoping reviews,
700 the results are limited by the literature available. The decision to use broad search terms
701 maximised the sensitivity but reduced the specificity of the searches. As the aim of this
702 review was to provide an overview of the field, this was felt to be justified. While the
703 inclusion of small underpowered trials and pilot studies has provided a broad picture of
704 relevant research, they may have overinflated the effectiveness of visual interventions. The
705 heterogeneity in both outcome measures and intervention methodologies made
706 comparison between studies challenging. It is recognised that there was also considerable
707 heterogeneity between the visual aspects of the interventions. However, considering the
708 studies in groups by intervention type provided some common ground for analysis.
709
710 There are also several limitations to the BCT coding process. BCTs can only be identified in
711 an intervention if the intervention is described in sufficient detail, demonstrated in this
712 review by one study having no coded BCTs. The analysis of the quality of intervention
713 reporting confirmed that intervention reporting was not always adequate. Unintentional
714 BCTs can be incorporated into the intervention where they form part of usual care. Coding
715 only those BCTs that appeared to be unique to the intervention attempts to mitigate for
716 these 'extra' BCTs. Additionally, coding the complete intervention may have identified BCTs
717 that were not attributed solely to the visual element. However, it is acknowledged that
718 visuals rarely act in isolation: King and Lazard suggest that within health communication
719 there are few practical applications of visuals without some accompanying written or
720 spoken narrative[97]. It was therefore considered justifiable to code the entire intervention.
721 While the BCTs used were those defined in the BCT Taxonomy v1, there is still the potential
722 for differences in interpretation of the BCT definitions. All 44 studies included in this review
723 were independently coded by two coders; this collaborative approach added rigour and
724 minimised the likelihood of miscoding.
725
726 **Implications for intervention design**
727
728 These findings suggest that the elements associated with visual interventions may differ
729 depending on the purpose of the intervention. Most educational interventions were single
730 component, accessed on multiple occasions. Almost all medication reminder interventions
731 were self-directed with multiple interactions, with all but one intervention being
732 multifaceted. Most conceptualisation interventions were facilitated, single component and
733 accessed once.
734
735 BCT *5.1 Information about health consequences* and *5.2 Salience of consequences* from the
736 '*Natural consequences*' category, BCTs from the '*Social support*' category and BCT *4.1*
737 *Instruction on how to perform the behaviour* were particularly prevalent in interventions
738 exploring illness beliefs and medication adherence, including those that were considered

effective. Additionally, BCTs from the '*Feedback and monitoring'* category, BCT *7.1 Prompts and cues* and *9.1 Credible source* were also identified in many adherence interventions. BCTs *5.1 Information about health consequences*, *5.2 Salience of consequences* and *2.6 Biofeedback* were present in most effective studies where the positive effect persisted for over 1 year, suggesting that those visual interventions encourage sustained behaviour change by illustrating for the participant 'what are the potential consequences?', 'why are these consequences important to me?' and 'what is my current state of health for this condition?'. Whilst the presence of a BCT in an effective study does not guarantee that the BCT was instrumental to the study success, indeed many of the BCTs were also identified in non-effective interventions, inclusion of these BCTs may provide a foundation for an effective intervention.

This review found that 15 of the 39 studies measuring adherence outcomes used only one adherence measure and that of those using multiple measures there was not always consistency between outcomes. It is recognised that there is no one 'best' measure of adherence and intervention context can influence the most appropriate method to use [98]. It is therefore suggested that using multiple measures of adherence is preferable [99,100]. The TIDieR analysis in this review demonstrated that the standard of intervention reporting is sometimes insufficient. Detailed reporting would allow BCTs to be more easily identified and therefore enable replication of interventions.

Conclusions

This scoping review methodology allowed for a novel and comprehensive overview of the literature regarding visual interventions and their influence on adherence and illness beliefs. Some trends were noted between the studies; in particular, the prevalence of the BCT '*Salience of consequences*' in effective visual interventions for both outcomes. This review identifies the overarching elements and BCTs common to visual interventions targeting illness beliefs and medication adherence for chronic conditions and demonstrates the utility of visuals within a variety of intervention types. Intervention designers are provided with a foundation for future research in this area.

794
795
796
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Table 1: Keywords used in scoping review searches

Illness	Visual	Adherence	Illness perception	Intervention	Medication
illness disease health chronic condition long term condition	visuali*ation visuali*e pict* image* illustration illustrated graphic game gaming app computer design mobile health m-health e-health animation	initiation implementation persistence discontinuation adherence non-adherence compliance concordance non-compliance	representation *adj* illness "self-regulatory model" "common sense model" "illness perception" belief "illness belief"	intervention study trial personali*ed	medication medicine therapy treatment

Table 2: Summary of study characteristics

Lead Author	Year	Title	Study Type	Country	Number of Participants	Participant age (where stated)	Study length	Condition studied
Anderson	2018	Mobile health intervention for youth with sickle cell disease: Impact on adherence, disease knowledge, and quality of life	Pilot Pre-post	USA	32 intervention No control	7 - 18 years old	90 days	Sickle cell disease

Anglada-Martinez	2016	Feasibility and Preliminary Outcomes of a Web and Smartphone–Based Medication Self-Management Platform for Chronically Ill Patients	Single arm Pre-post	Spain	62 intervention No control	>18 years old	6 months	Cardiovascular (heart failure / hypertension / dyslipidaemia) HIV
Ben-Zeev	2014	Feasibility, Acceptability, and Preliminary Efficacy of a Smartphone Intervention for Schizophrenia	Pre-post	USA	33 intervention No control	> 18 years old	1 month	Schizophrenia
Brown	1997	Educational video game for juvenile diabetes: results of a controlled trial	Described as 'randomized controlled field experiment'	USA	31 intervention 28 control	8 - 16 years old	6 months	Type 1 diabetes
Cordasco	2009	A Low-Literacy Medication Education Tool for Safety-Net Hospital Patients	RCT	USA	142 intervention 144 control	>18 years old	4 weeks	Inpatients to cardiology, internal medicine, renal
DeWalt	2006	A heart failure self-management program for patients of all literacy levels: A randomized, controlled trial	RCT	USA	62 intervention 65 control	30 - 80 years old	12 months	Outpatients at general medicine / cardiology
Ebrahimabadi	2018	Infographics or video; which one is more effective in asthmatic patients' health? a randomized clinical trial	RCT	Iran	41 intervention 39 control	20 - 65 years old	1 month	Asthma

Favier	2018	Feasibility of a musculoskeletal ultrasound intervention to improve adherence in juvenile idiopathic arthritis: a proof-of concept trial.	Proof-of-concept study Pre-post	USA	11 intervention	0 - 17 years old	2 - 3 months	Arthritis (juvenile idiopathic arthritis)
Gazmarian	2010	Effect of a Pharmacy-Based Health Literacy Intervention and Patient Characteristics on Medication Refill Adherence in an Urban Health System	RCT	USA	173 intervention 102 control	>18 years old	6 months	Any chronic condition (pharmacy patients in hospital setting and associated community pharmacy)
Hawkins	2014	Testing a novel pictorial medication sheet to improve adherence in veterans with heart failure and cognitive impairment.	Pre-post	USA	36 intervention No control	> 18 years old	4 months	Cardiovascular (heart failure and cognitive impairment)
Heisler	2014	Comparison of community health worker-led diabetes medication decision-making support for low-income Latino and African American adults with diabetes using e-health tools versus print materials: a randomized, controlled trial	RCT	USA	93 intervention 95 control	>21 years old	3 months	Type 2 diabetes

Holzheimer	1998	Educating young children about asthma: comparing the effectiveness of a developmentally appropriate asthma education video tape and picture book	RCT	Australia	16 group 1 13 group 2 12 group 3 15 control	2 -5 years	4 months	Asthma
Jones (2016)	2016	Using Animation to Improve Recovery from Acute Coronary Syndrome: A Randomized Trial	RCT	New Zealand	35 intervention 35 control	>18 years old	7 weeks	Cardiovascular (acute coronary syndrome)
Jones (2017)	2017	The Impact of 3-D Models versus Animations on Perceptions of Osteoporosis and Treatment Motivation: A Randomised Trial	Pre-post	New Zealand	64 computer animation 64 3-D model	females aged 50 +	one 30-minute session	Osteoporosis
Jones (2019)	2019	The use of a brief, active visualisation intervention to improve adherence to antiretroviral therapy in non-adherent patients in South Africa	RCT	South Africa	56 intervention 55 control	>15 years old	single 10-minute session	HIV
Joplin	2016	Pilot study assessing the novel use of musculoskeletal ultrasound in patients with rheumatoid arthritis to improve patient attitudes and adherence to medication.	Pilot study Pre-post	Australia	18	> 18 years old	10 days	Arthritis (rheumatoid arthritis)

Kalia	2006	Visualizing coronary calcium is associated with improvements in adherence to statin therapy	pre-post	USA	505	adults mean age 61 +/- 10 years	minimum of 1 year (some participants followed for up to 10 years)	Cardiovascular
Kalichman	2013	Randomized clinical trial of HIV treatment adherence counseling interventions for people living with HIV and limited health literacy	RCT	USA	148 pictographs 157 standard counselling (comparator) 141 general health improvement counselling (control)	> 18 years old	1 year	HIV
Karamanidou	2008	Improving haemodialysis patients' understanding of phosphate-binding medication: a pilot study of a psycho-educational intervention designed to change patients' perceptions of the problem and treatment.	Pilot study RCT	UK	19 intervention 20 control	Adults (age unspecified)	4 months	End stage renal disease

Kharrazi	2009	Improving Healthy Behaviors in Type 1 Diabetic Patients by Interactive Frameworks.	Between group within-subject (crossover study)	USA	42	7 - 13 years old	6 weeks	Type 1 diabetes
Kato	2008	A video game improves behavioural outcomes in adolescents and young adults with cancer: A randomized trial.	RCT	USA Canada Australia	197 intervention 178 control	13 - 29 years old	3 months	Cancer
Kleyer	2017	Development of three-dimensional prints of arthritic joints for supporting patients' awareness to structural damage	Qualitative interviews	Germany	40 intervention (10 healthy participants 15 rheumatoid arthritis 15 psoriatic arthritis)	No age exclusions specified All participants were > 18 years old	single 20-minute interview	Arthritis (rheumatoid and psoriatic)
Kosse	2019	The effect of a mHealth intervention on adherence in adolescents with asthma: A randomized clinical trial	RCT	Netherlands	103 intervention 150 control	12 - 18 years	6 months	Asthma
Kripalani	2012	Improving medication adherence through graphically enhanced interventions in coronary heart disease (IMAGE-CHD): a randomized controlled trial	RCT	USA	117 PictureRx and reminder 124 picture Rx 103 reminder 96 control	> 18 years old	1 year	Cardiovascular (coronary heart disease)

Lakshminarayana	2017	Using a smartphone-based self-management platform to support medication adherence and clinical consultation in Parkinson's disease	RCT	UK	104 intervention 108 control	Not stated mean age 60.31 (SD 9.73)	16 weeks	Parkinson's disease
Mansoor	2006	Medicines information and adherence in HIV/AIDS patients	RCT	South Africa	40 complex patient information leaflet (PIL) 40 simple PIL 40 control	> 16 years old	14 days	Long-term treatment for pneumocystis carinii pneumonia (PCP) in HIV patients
Martin	2012	Improving medication management among at-risk older adults	Pilot quality improvement project pre-post	USA	20 intervention	> 18 mean age 75.25 (SD 8.77), range 59-89	6 weeks	Any chronic condition (older adults using an adult day centre. All had at least 2 chronic conditions)
Mendelson	2017	Comics as an educational tool for children with juvenile idiopathic arthritis.	Pre-post	Israel	61 intervention	8 - 18 years old	1 year	Arthritis (juvenile idiopathic arthritis)

Mira	2014	A Spanish pillbox app for elderly patients taking multiple medications: Randomized controlled trial	RCT	Spain	51 intervention 48 control	> 65 years old	3 months	Elderly patients with chronic conditions
Mohan	2014	Improving medication understanding among Latinos through illustrated medication lists	RCT	USA	103 intervention 105 usual care	> 18 years old	1 week	Diabetes
Molan	2018	Evaluating the Effectiveness of an Online Cardiac Rehabilitation Resource (www.svhhearthealth.com.au) in Improving Knowledge and Confidence for Patients With Newly Diagnosed Cardiac Conditions: A Pre-Experimental Pilot Study	Pilot study Pre-post	Australia	67 intervention	No age exclusions specified. Mean age of participants 63 years (+/- 11 years)	one 30-minute session	Cardiovascular
Mols	2015	Visualisation of Coronary Calcification: Influence on Risk Modification.	RCT	Denmark	96 intervention 96 control	No age exclusions specified. Mean age of participants 61 years (SD 12)	6 months	Cardiovascular
Monroe	2018	Randomized controlled trial of a pictorial aid intervention for medication adherence among HIV-positive patients with comorbid diabetes or hypertension	RCT	USA	23 intervention 23 control	> 18 years old	180 days	HIV with comorbid diabetes or hypertension

Montori	2011	Use of a decision aid to improve treatment decisions in osteoporosis: The osteoporosis choice randomized trial	RCT	USA	52 intervention

48 control | Women aged >50 years old | 6 months | Osteoporosis |
| Moore | 2011 | A collaborative awareness system for chronic disease medication adherence applied to HIV infection. | Pilot

Pre-post | USA | 4 intervention | No age exclusions specified. Participant age ranged from 43 - 61 years old | 4 weeks | HIV |
| Murray | 2007 | Pharmacist intervention to improve medication adherence in heart failure: a randomized trial. | RCT | USA | 122 Intervention

192 control | > 50 years old | 12 months | Cardiovascular (heart failure) |
| Näslund | 2019 | Visualization of asymptomatic atherosclerotic disease for optimum cardiovascular prevention (VIPVIZA): a pragmatic, open-label, randomised controlled trial | RCT | Sweden | 1749 intervention

1783 control | 40 years old | 1 year | Cardiovascular |
| Negarandeh | 2013 | Teach-back and pictorial image educational strategies on knowledge about diabetes and medication/dietary adherence among low health literate patients with type 2 diabetes | RCT | Kurdistan | 45 'teach back' 45 pictorial image 45 usual care | not stated | 6 weeks | Type 2 diabetes |
| Perera | 2014 | Effect of a Smartphone Application Incorporating Personalized Health-Related Imagery on Adherence to Antiretroviral Therapy: A Randomized Clinical Trial | RCT | New Zealand | 17 intervention

11 control | No age exclusions specified. Average age 46 years old (range 30-65 years | 3 months | HIV |

						old)	
Rees	2013	Feedback of personal retinal images appears to have a motivational impact in people with non-proliferative diabetic retinopathy and suboptimal HbA1c: findings of a pilot study	Pilot study RCT	Australia	15 Intervention 10 control	> 18 years old	3 months	Diabetes (type 1 or type 2)
Rozanski	2011	Impact of Coronary Artery Calcium Scanning on Coronary Risk Factors and Downstream Testing. The EISNER (Early Identification of Subclinical Atherosclerosis by Noninvasive Imaging Research) Prospective Randomized Trial	RCT	USA	1424 intervention 713 control	< 80 years old	4 years	Cardiovascular
Saenghow	2018	Epilepsy video animation: impact on knowledge and drug adherence in pediatric epilepsy patients and caregivers	RCT	Thailand	126 intervention 88 control	1 month - 15 years	3 months	Epilepsy
Shah	2016	A Patient-Centered Tablet Application for Improving Medication Adherence after a Drug-Eluting Stent	Pilot RCT	USA	13 intervention 11 control	> 50 years old	3 months	Cardiovascular (stent patients)

Stephens	2016	3-D bone models to improve treatment initiation among patients with osteoporosis: A randomised controlled pilot trial	RCT	New Zealand	29 intervention 29 control	> 60 years old	2 months	Osteoporosis
Whiteley	2018	Enhancing health among youth living with HIV using an iPhone game	RCT	USA	32 intervention 29 control	14 - 26 years old	16 weeks	HIV

Table 3: Summary of study features with BCT coding: conceptualisation interventions

Lead study author	Description of visual	Intervention facilitator	Multifaceted intervention	Intervention 'dose' (single/multiple exposures)	Positive medication adherence outcomes demonstrated	Positive illness belief outcomes demonstrated	Identified BCTs
Favier *Feasibility of a musculoskeletal ultrasound intervention to*	Medical scan pictures	Rheumatologist	No	Single	No	No	2.6 Biofeedback

improve adherence in juvenile idiopathic arthritis: a proof-of concept trial.							
Heisler *Comparison of community health worker-led diabetes medication decision-making support for low-income Latino and African American adults with diabetes using e-health tools versus print materials: a randomized, controlled trial*	Animated digital tablet-based visuals paper-based pictorial material	Community health worker	Yes	Single	Yes	Yes	1.1 Goal setting (behaviour) 1.4 Action plans 3.3 Social support (emotional) 5.1 Information about health consequences 5.2 Salience of consequences 9.1 Credible source
Jones (2016) *Using Animation to Improve Recovery from Acute Coronary Syndrome: A Randomized Trial*	Animated pictures (iPad)	Researcher	No	Single (with option to view again in their own time via a website link)	No	Yes	3.1 Social support (unspecified) 5.1 Information about health consequences 5.2 Salience of consequences
Jones (2017) *The Impact of 3-D Models versus Animations on Perceptions of Osteoporosis and*	3-D model of osteoporotic bone Animated computer model of osteoporotic bone	Researcher	No	Single	n/a	Yes	5.2 Salience of consequences

Treatment Motivation: A Randomised Trial							
Jones (2019) *The use of a brief, active visualisation intervention to improve adherence to antiretroviral therapy in non-adherent patients in South Africa*	3-D stylised representation of a body	Research assistant	No	Single	Yes	No	5.1 Information about health consequences 5.2 Salience of consequences 6.1 Demonstration of the behaviour
Joplin *Pilot study assessing the novel use of musculoskeletal ultrasound in patients with rheumatoid arthritis to improve patient attitudes and adherence to medication.*	Medical scan pictures	Rheumatologist	No	Single	No	Yes	2.6 Biofeedback
Kalia *Visualizing coronary calcium is associated with improvements in adherence to statin therapy*	Medical scan pictures	Researcher	No	Single	Yes	n/a	2.6 Biofeedback 5.1 Information about health consequences 5.2 Salience of consequences
Karamanidou	3-D representation of a stomach	Researcher	Yes	Single	No	Yes	5.1 Information about health consequences

Improving haemodialysis patients' understanding of phosphate-binding medication: a pilot study of a psycho-educational intervention designed to change patients' perceptions of the problem and treatment.							5.2 Salience of consequences 6.1 Demonstration of the behaviour
Kleyer *Development of three-dimensional prints of arthritic joints for supporting patients' awareness to structural damage*	3-D models of both healthy and erosive MCP joints	Researcher	No	Single	Yes	Yes	5.2 Salience of consequences
Mols *Visualisation of Coronary Calcification: Influence on Risk Modification.*	Medical scan pictures	Nurse	Yes	Single	Partial (positive sub-group analysis)	n/a	2.6 Biofeedback 3.1 Social Support (unspecified) 5.2 Salience of consequences 9.2 Pros and cons
Moore *A collaborative*	Animated pictures	Self-directed	Yes	Multiple	Yes	n/a	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour

awareness system for chronic disease medication adherence applied to HIV infection.								2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instructions on how to perform the behaviour 5.1 Information about health consequences 5.2 Salience of consequences 7.1 Prompts/ cues 10.4 Social reward
Näslund *Visualization of asymptomatic atherosclerotic disease for optimum cardiovascular prevention (VIPVIZA): a pragmatic, open-label, randomised controlled trial*	Medical scan pictures (stylised representation)	Self-directed	No	Multiple	Yes	n/a	2.6 Biofeedback 3.1 Social support (unspecified) 5.1 Information about health consequences 5.2 Salience of consequences
Perera *Effect of a Smartphone Application Incorporating Personalized*	Animated pictures	Self-directed	Yes	Multiple	Yes	Yes	2.7 Feedback on outcomes of behaviour 5.2 Salience of consequences

Health-Related Imagery on Adherence to Antiretroviral Therapy: A Randomized Clinical Trial								
Rees *Feedback of personal retinal images appears to have a motivational impact in people with non-proliferative diabetic retinopathy and suboptimal HbA1c: findings of a pilot study*	Medical scan pictures	Research orthoptist	No	Single	n/a	Yes	2.6 Biofeedback 3.1 Social support (unspecified) 5.1 Information about health consequences 5.2 Salience of consequences 9.1 Credible source
Rozanski *Impact of Coronary Artery Calcium Scanning on Coronary Risk Factors and Downstream Testing. The EISNER (Early Identification of Subclinical Atherosclerosis by Noninvasive Imaging Research) Prospective Randomized Trial*	Medical scan pictures	Nurse practitioner	No	Single	Yes	n/a	2.6 Biofeedback 5.1 Information about health consequences 5.2 Salience of consequences 9.1 Credible source

Shah *A Patient-Centered Tablet Application for Improving Medication Adherence after a Drug-Eluting Stent*	Tablet-based educational material 2-D illustration of patient's heart depicting the extent of blood vessel blockage and their stent placement	Self-directed	No	Multiple	No	n/a	5.1 Information about health consequences 5.2 Salience of consequences 6.2 social comparison 9.3 Comparative imagining of future outcomes
Stephens *3-D bone models to improve treatment initiation among patients with osteoporosis: A randomised controlled pilot trial*	3-D model of osteoporotic bone	Physician	No	Single	Yes	No	5.1 Information about health consequences 5.2 Salience of consequences 9.1 Credible source 9.2 Pros and cons

Table 4: Summary of study features with BCT coding: educational interventions

Lead study author	Description of visual	Intervention facilitator	Multifaceted intervention	Intervention 'dose' (single/multiple exposures)	Positive medication adherence outcomes demonstrated	Positive illness belief outcomes demonstrated	Identified BCTs
Anderson *Feasibility and Preliminary Outcomes of a Web and*	Smartphone based pictorial educational material	Clinic staff	Yes	Multiple	Yes	n/a	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)

Smartphone–Based Medication Self-Management Platform for Chronically Ill Patients							5.1 Information about health consequences 9.1 Credible source
Ben-Zeev *Feasibility, Acceptability, and Preliminary Efficacy of a Smartphone Intervention for Schizophrenia*	Smartphone based pictorial educational material	Research staff	Yes	Multiple	n/a	No	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.1 Monitoring of behaviour by others without feedback 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 7.1 Prompts/cues 11.2 Reduce negative emotion 13.3 Incompatible beliefs
Brown *Educational video game for juvenile diabetes: results of a controlled trial*	Animated game graphics	Self-directed	No	Multiple	n/a	No	3.1 Social support (unspecified) 5.1 Information about health consequences 8.1 Behavioural practice/ rehearsal
DeWalt	Paper based pictorial educational material	Nurse or	Yes	Multiple	n/a	Yes	1.3 Goal setting (outcome)

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		clinical pharmacist					1.4 Action planning
A heart failure self-management program for patients of all literacy levels: A randomized, controlled trial							2.2 Feedback on behaviour 2.4 Self-monitoring of outcome of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 7.1 Prompts/ cues 8.1 Behavioural practice/ rehearsal 9.1 Credible source
Ebrahimabadi *Infographics or video; which one is more effective in asthmatic patients' health? a randomized clinical trial*	Paper based pictorial educational material	Nurse (not a specialist in the study condition)	No	Multiple	Yes	n/a	9.1 Credible source
Holzheimer *Educating young children about asthma:*	Illustrated picture book	Self-directed	Some participants (four-armed study with one group	Multiple	No	n/a	2.1 Monitoring of behaviour by others with feedback 4.1 Instruction on how to perform a behaviour

comparing the effectiveness of a developmentally appropriate asthma education video tape and picture book			using both video and book)					5.1 Information about health consequences 6.1 Demonstration of the behaviour 6.2 Social comparison 6.3 Information about other's approval 11.2 Reduce negative emotions
Kalichman *Randomized clinical trial of HIV treatment adherence counseling interventions for people living with HIV and limited health literacy*	Paper based pictorial educational material Picture corresponding to each medication in regime	Counsellor	Yes	Multiple	No	n/a	1.2 Problem solving 1.4 Action planning 4.1 Instruction on how to perform the behaviour 7.1 Prompts/ cues 8.1 Behavioural practice/ rehearsal 9.1 Credible source 12.5 Adding objects to the environment
Kato *A video game improves behavioural outcomes in adolescents and*	Animated computer game visuals	Self-directed	No	Multiple	Yes	Yes	4.1 Instruction on how to perform a behaviour 5.1 Information about health consequences 8.1 Behavioural practice/ rehearsal

young adults with cancer: A randomized trial.							16.3 Vicarious consequences
Kharrazi

Improving Healthy Behaviors in Type 1 Diabetic Patients by Interactive Frameworks. | Animated computer game visuals | Self-directed | No | Multiple | Yes | Yes | 3.2 Social support (practical)

3.3 Social support (emotional)

5.1 Information about health consequences

6.2 Social comparison

7.1 Prompts/ cues

10.10 Reward (outcome)

14.3 Remove reward |
| Kosse

The effect of a mHealth intervention on adherence in adolescents with asthma: A randomized clinical trial | Smartphone based pictorial educational material | Community pharmacist | Yes | Multiple | Partial (positive sub-group analysis) | n/a | 2.3 Self-monitoring of behaviours

2.4 Self-monitoring of outcome(s) of behaviours

3.1 Social support (unspecified)

7.1 Prompts/ cues

9.1 Credible source |
| Mansoor

Medicines information and adherence in HIV/AIDS patients | Paper based patient medicine information leaflet incorporating pictograms. | Self-directed | No | Multiple | Yes | n/a | No BCTs coded |

Mendelson *Comics as an educational tool for children with juvenile idiopathic arthritis.*	Illustrated picture book	Self-directed	No	Single	No	n/a	5.1 Information about health consequences 5.3 Information about social and environmental consequences
Molan *Evaluating the Effectiveness of an Online Cardiac Rehabilitation Resource (www.svhhearthe alth.com.au) in Improving Knowledge and Confidence for Patients With Newly Diagnosed Cardiac Conditions: A Pre-Experimental Pilot Study*	2-D illustrations and 3-D animations	Self-directed	No	Single	n/a	Yes	5.1 Information about health consequences 5.2 Salience of consequences 5.3 Information about social and environmental consequences
Montori *Use of a decision aid to improve treatment decisions in osteoporosis: The osteoporosis choice randomized trial*	Pictorial icons used to illustrate risk	Clinicians	No	Multiple – patients used the decision aid in a consultation and then took it home	No	n/a	4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 6.2 Social comparison 9.1 Credible source 9.2 Pros and cons 9.3 Comparative imagining of future

							outcomes
Negarandeh *Teach-back and pictorial image educational strategies on knowledge about diabetes and medication/dietary adherence among low health literate patients with type 2 diabetes*	Educational Medication reminder	Community health nurse	Yes	Multiple	Yes	n/a	4.1 Instruction on how to perform the behaviour
Saengow *Epilepsy video animation: impact on knowledge and drug adherence in pediatric epilepsy patients and caregivers*	Animated pictures	Clinician	No	Single	Yes	n/a	5.3 Information about social and environmental consequences 9.1 Credible source
Shah *A Patient-Centered Tablet Application for Improving Medication Adherence after a Drug-Eluting Stent*	Tablet-based educational material 2-D illustration of patient's heart depicting the extent of blood vessel blockage and their stent placement	Self-directed	No	Multiple	No	n/a	5.1 Information about health consequences 5.2 Salience of consequences 6.2 Social comparison 9.3 Comparative imagining of future outcomes
Whiteley	Animated game	Self-directed	No	Multiple	Partial	No	3.1 Social support (unspecified)

Lead study author	Description of visual	Intervention facilitator	Multifaceted intervention	Intervention 'dose' (single/multiple exposures)	Positive medication adherence outcomes demonstrated	Positive illness belief outcomes demonstrated	Identified BCTs
Enhancing health among youth living with HIV using an iPhone game	graphics				(positive sub-group analysis)		5.1 Information about health consequences 5.2 Salience of consequences 5.3 Information about social and environmental consequences 7.1 Prompts/ cues 9.1 Credible source 9.3 Comparative imagining of future outcomes 10.4 Social reward

Table 5: Summary of study features with BCT coding: medication reminder interventions

Lead study author	Description of visual	Intervention facilitator	Multifaceted intervention	Intervention 'dose' (single/multiple exposures)	Positive medication adherence outcomes demonstrated	Positive illness belief outcomes demonstrated	Identified BCTs
Anglada-Martinez *Feasibility and Preliminary Outcomes of a Web and Smartphone–Based Medication Self-*	Picture corresponding to each medication in regime	Self-directed	Yes	Multiple	Yes	n/a	2.1 Monitoring of behaviour by others without feedback 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)

Management Platform for Chronically Ill Patients							4.1 Instruction on how to perform a behaviour 7.1 Prompts/cues
Cordasco *A Low-Literacy Medication Education Tool for Safety-Net Hospital Patients*	Picture corresponding to each medication in regime	Self-directed	No	Multiple	No	n/a	4.1 Instruction on how to perform a behaviour
Gazmararian *Effect of a Pharmacy-Based Health Literacy Intervention and Patient Characteristics on Medication Refill Adherence in an Urban Health System*	Picture corresponding to each medication in regime	Self-directed	Yes	Multiple	No	n/a	4.1 Instruction on how to perform a behaviour 7.1 Prompts/cues
Hawkins *Testing a novel pictorial medication sheet to improve adherence in veterans with heart failure and cognitive impairment.*	Picture corresponding to each medication in regime	Self-directed	Yes	Multiple	Yes	n/a	4.1 Instruction on how to perform a behaviour 7.1 Prompts/cues
Kalichman *Randomized clinical trial of HIV treatment adherence counseling interventions for people living with HIV and limited health*	Picture corresponding to each medication in regime Paper based	Counsellor	Yes	Multiple	No	n/a	1.2 Problem solving 1.4 Action planning 4.1 Instruction on how to perform the behaviour

literacy	pictorial educational material						7.1 Prompts/ cues 8.1 Behavioural practice/ rehearsal 9.1 Credible source 12.5 Adding objects to the environment
Kripalani *Improving medication adherence through graphically enhanced interventions in coronary heart disease (IMAGE-CHD): a randomized controlled trial*	Picture corresponding to each medication in regime	Self-directed	Yes	Multiple	No	n/a	3.1 Social support (unspecified) 4.1 Instruction on how to perform a behaviour 7.1 Prompts/cues
Lakshminarayana *Using a smartphone-based self-management platform to support medication adherence and clinical consultation in Parkinson's disease*	Picture corresponding to each medication in regime	Self-directed	Yes	Multiple	Yes	No	2.4 Self-monitoring of outcome(s) of behaviour 5.1 Information about health consequences 7.1 Prompts/ cues
Martin *Improving medication management among at-risk older adults*	Picture corresponding to each medication in regime	Self-directed	No	Multiple	Yes	Yes	4.1 Instruction on how to perform a behaviour
Mira *A Spanish pillbox app*	Picture corresponding to each	Self-directed	Yes	Multiple	Yes	n/a	2.1 Monitoring of behaviour by others without feedback

for elderly patients taking multiple medications: Randomized controlled trial	medication in regime						4.1 Instruction on how to perform a behaviour

7.1 Prompts/cues |
| Mohan

Improving medication understanding among Latinos through illustrated medication lists | Picture corresponding to each medication in regime | Self-directed | Yes | Multiple | No | n/a | 4.1 Instruction on how to perform a behaviour

7.1 Prompts/cues |
| Monroe

Randomized controlled trial of a pictorial aid intervention for medication adherence among HIV-positive patients with comorbid diabetes or hypertension | Picture corresponding to each medication in regime | Self-directed | No | Multiple | No | n/a | 4.1 Instruction on how to perform a behaviour |
| Murray

Pharmacist intervention to improve medication adherence in heart failure: a randomized trial. | Picture corresponding to each medication in regime | Pharmacist counselling and self-directed pictorial medication schedule | Yes | Multiple | Yes | n/a | 1.2 Problem solving

2.1 Monitoring of behaviour by others without feedback

3.1 Social support (unspecified)

3.2 Social support (practical)

4.1 Instruction on how to perform the behaviour

5.1 Information about health consequences |

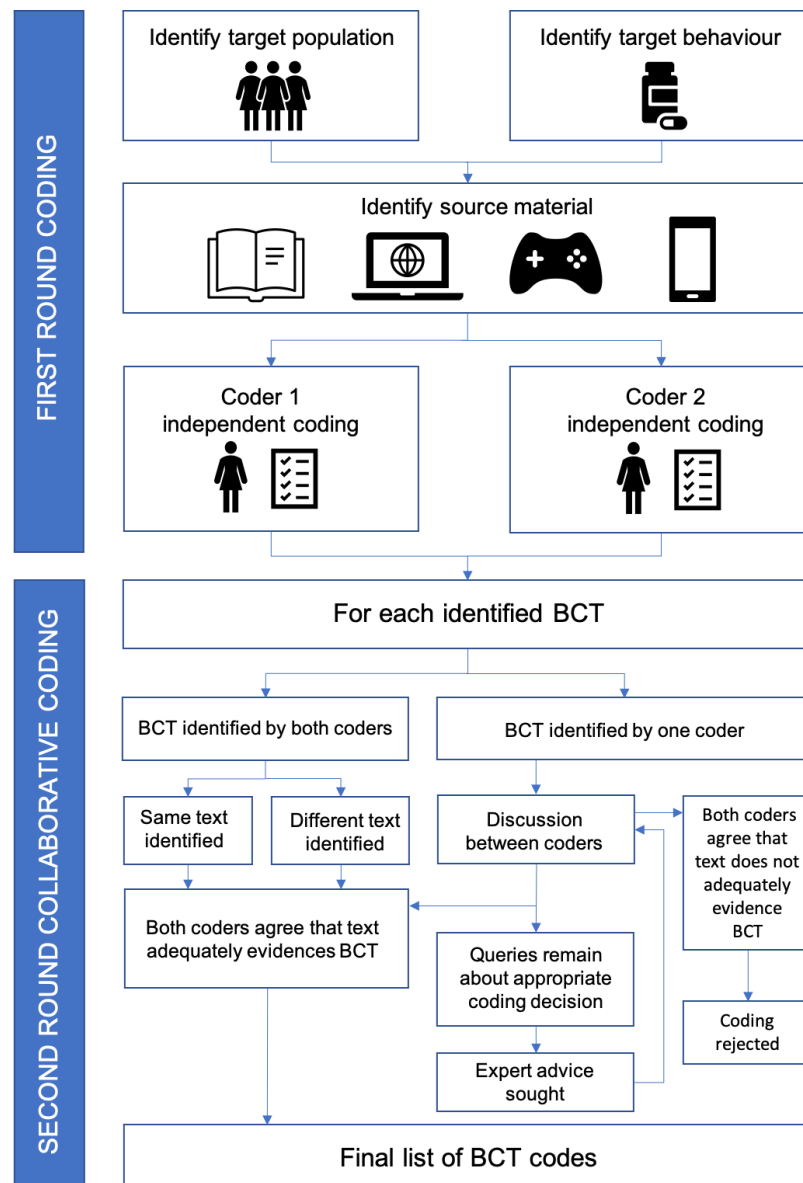|							6.1 Demonstration of the behaviour
							7.1 Prompts/ cues

Figures

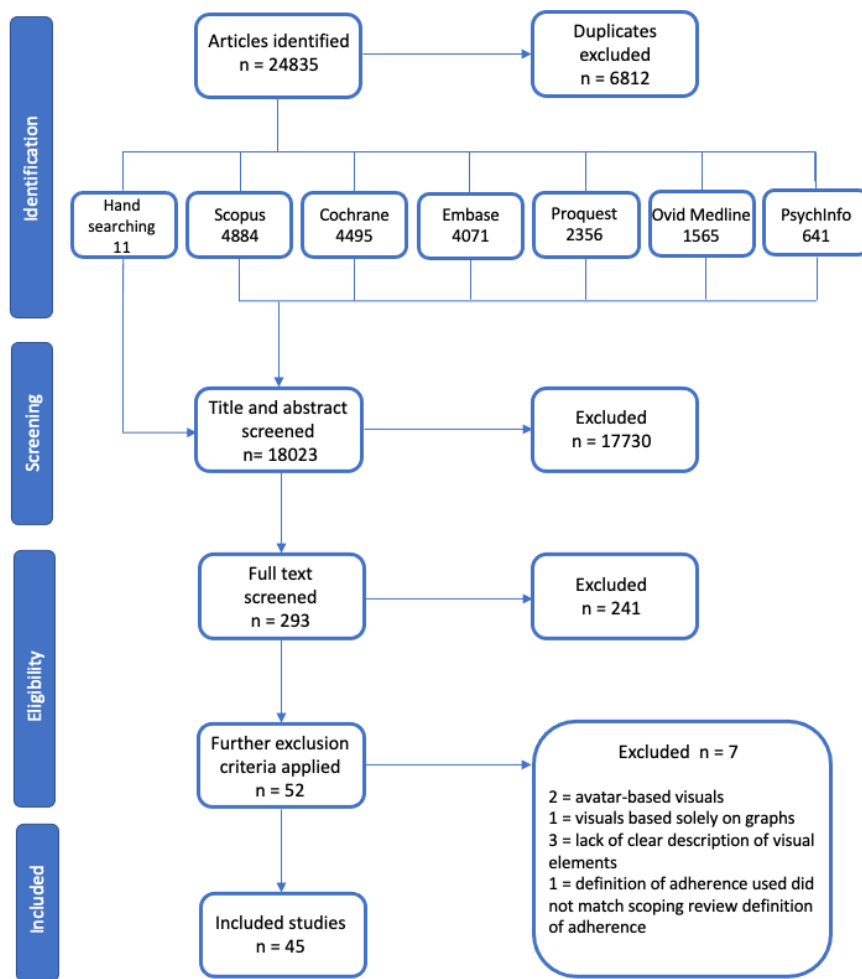Figure 1: The Behaviour Change Technique (BCT) coding process

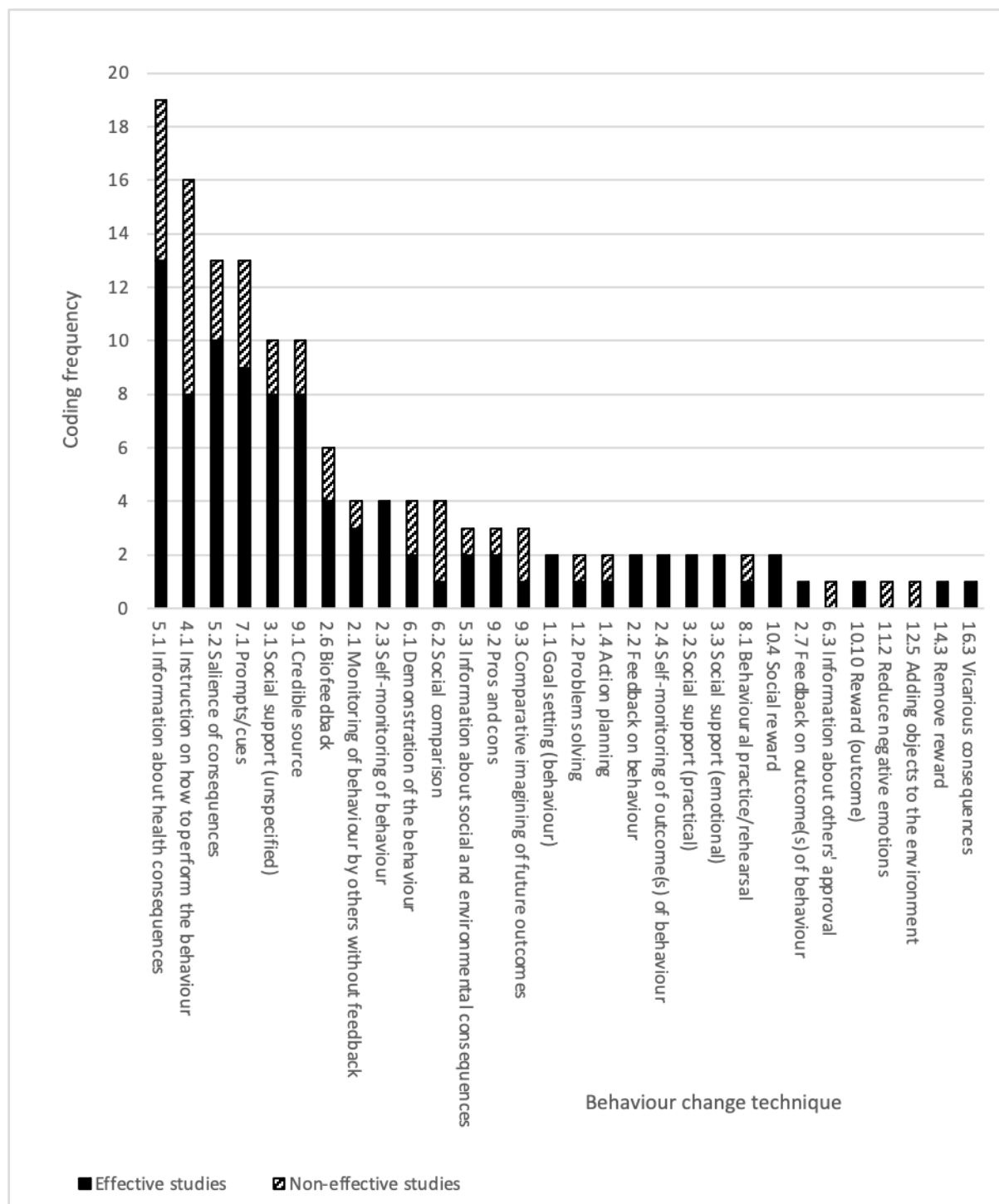Figure 2: PRISMA flow diagram of study selection

Figure 3: BCTs coded for effective and non-effective quantitative studies: medication adherence outcomes
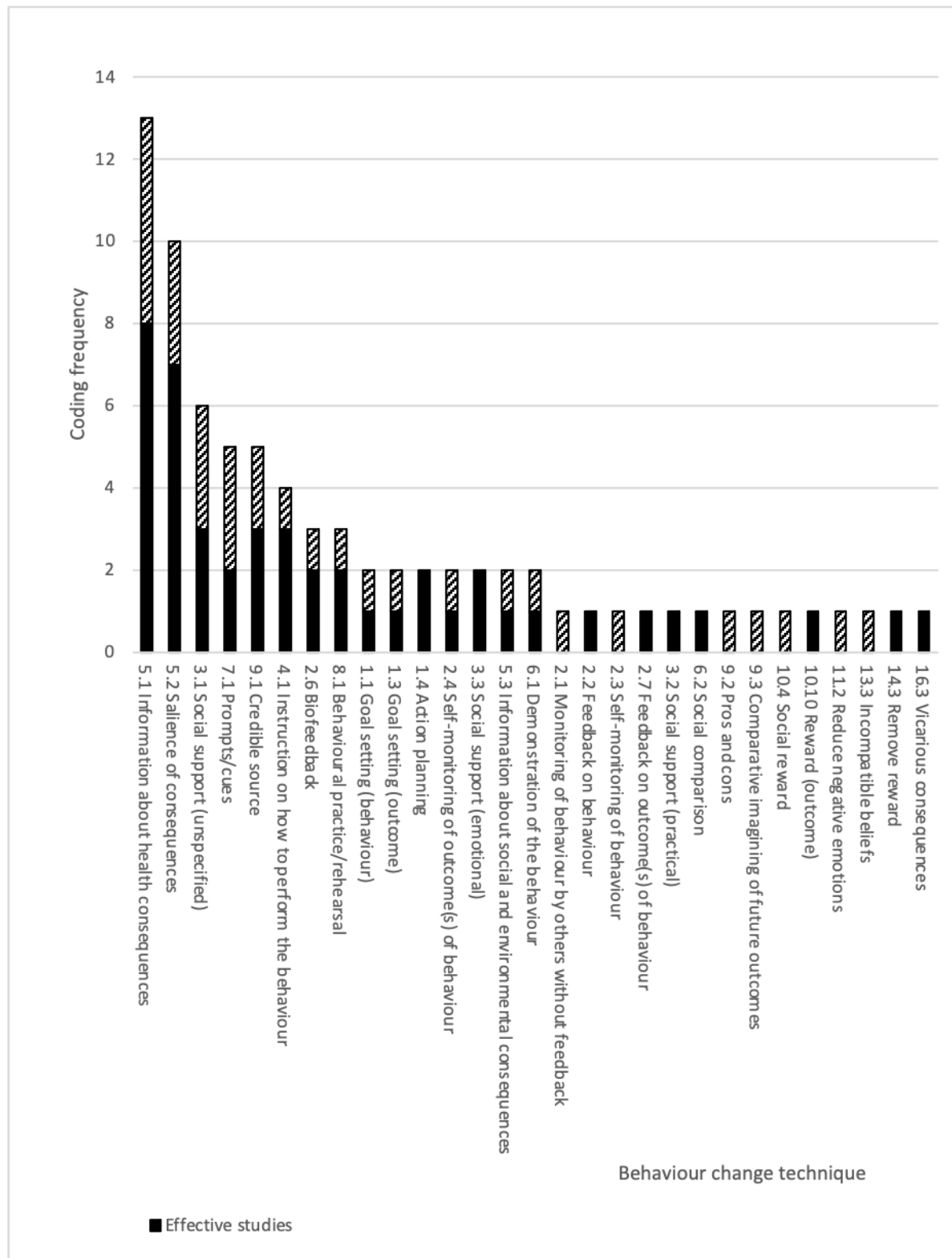
Figure 4: BCTs coded for effective and non-effective quantitative studies: illness beliefs outcomes