**Flexible synthesis to deliver relevant evidence for decision-making**

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The use of systematic reviews and related methods to collate and summarise evidence is considered one of the great intellectual achievements of the last fifty years. Evidence synthesis has revolutionised entire fields, particularly medicine, producing remarkable insights. However, it is now appreciated that it also faces three serious problems. First, reviews often do not cover the issues or geography needed for specific decisions (1). Second, multiple, often conflicting, reviews are frequently produced on a topic resulting in inefficient use of research resources [(*1*, *2*)](https://paperpile.com/c/u4TPYy/anGy+KUoP). Third, reviews can rapidly become out-of-date [(*3*)](https://paperpile.com/c/u4TPYy/qrIz). In this policy forum we focus on a technique to deliver relevant evidence for particular decisions although our solution helps resolve all three topics.

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Huge amounts of resources have been dedicated to improving the robustness of scientific evidence [(*4*)](https://paperpile.com/c/u4TPYy/qenN), but the importance of relevant evidence has received relatively little attention [(*5*)](https://paperpile.com/c/u4TPYy/m8Uq). Even when evidence synthesis for an intervention of interest has been carried out its overall conclusions may be of limited relevance to decision-makers' needs if the review includes studies from contexts that differ from those of the decision-makers [(*4*, *6*)](https://paperpile.com/c/u4TPYy/qenN+gPod).

The key issue in considering relevance is transferability - the extent to which an intervention would have the same effect in a different context [(*7*, *8*)](https://paperpile.com/c/u4TPYy/m2Nx+fdh4). Myriad factors may influence the transferability of intervention effects from one context to another, which can be grouped into differences in (i) settings, (ii) target populations, (iii) how the intervention is delivered, and (iv) how outcomes are measured (see Table 1 for details of these). Differences in settings, target populations, and intervention delivery can cause real differences in outcomes, whereas apparent differences in outcomes may disappear if study methodologies are uniform [(*9*)](https://paperpile.com/c/u4TPYy/Vn9J).

Differences in context matter. This is particularly true for fields that are typified by high context variability, such as conservation biology [(*9*)](https://paperpile.com/c/u4TPYy/Vn9J), public health [(*16*)](https://paperpile.com/c/u4TPYy/2gKK), and education [(*12*)](https://paperpile.com/c/u4TPYy/XcBn). Evidence synthesis in the form of systematic review combined with meta-analysis can be valuable for informing decisions, but where intervention outcomes are highly context dependent it may be difficult to generalise about intervention effectiveness [(*16*)](https://paperpile.com/c/u4TPYy/2gKK). Subgroup analysis or meta-regression can be used to explain this variation, but the analyses that the authors consider interesting may not be those that the individual users need to help them make decisions.

One way to deal with varying contexts is to work with decision makers to co-produce new primary studies or systematic reviews that fit a specific context exactly [(*17*)](https://paperpile.com/c/u4TPYy/TAfK). However, this requires a considerable investment of time and money for each decision, may not be cost effective, difficult to carry out on a large scale, and it still produces evidence that is of limited relevance for people working in other different contexts [(*18*)](https://paperpile.com/c/u4TPYy/dfBH). An alternative solution involves determining the relevance of existing sources of evidence with respect to the local context, followed by an assessment of how effectiveness may change from one context to the next [(*16*, *18*)](https://paperpile.com/c/u4TPYy/dfBH+2gKK). We suggest this latter option presents a promising route for delivering relevant evidence.

**Table 1** - Different contextual factors that may influence how transferable intervention effects are from one context to another. This list is not exhaustive, see [(*4*)](https://paperpile.com/c/u4TPYy/qenN) for examples from clinical medicine and [(*6*)](https://paperpile.com/c/u4TPYy/gPod) for examples from biodiversity conservation.

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| --- | --- | --- | --- |
| **Contextual factor** | **Definition** | **Examples of these factors** | **Detailed examples** |
| Setting | The location where the intervention occurs and features relating to that location, excluding those relating to the target population. | * Differences in standard practice [(*4*)](https://paperpile.com/c/u4TPYy/qenN) * Cultural differences between countries/regions * Differences in biophysical conditions (e.g. climate) [(*6*)](https://paperpile.com/c/u4TPYy/gPod) * Differences in non-target ecological communities | Protected areas are more effective in reducing human pressure in economically developed regions than in less developed regions [(*10*)](https://paperpile.com/c/u4TPYy/Dorr) |
| Target population | The statistical population or sample on which the intervention aims to have an effect. | * Demographic differences [(*4*, *11*)](https://paperpile.com/c/u4TPYy/5y98+qenN) * Socioeconomic differences [(*4*, *11*)](https://paperpile.com/c/u4TPYy/5y98+qenN) * Differences in target species/taxonomic group [(*6*)](https://paperpile.com/c/u4TPYy/gPod) | Use of western, educated, industrialised, rich, and democratic subjects in studies of behaviour change interventions potentially limits the transferability of study results [(*11*)](https://paperpile.com/c/u4TPYy/5y98). |
| Intervention delivery | How an intervention is delivered | * Timing [(*4*)](https://paperpile.com/c/u4TPYy/qenN) * Intensity of intervention application [(*12*)](https://paperpile.com/c/u4TPYy/XcBn) * Frequency of application (i.e. is the intervention used once or multiple times) [(*12*)](https://paperpile.com/c/u4TPYy/XcBn) * Skill/experience of person applying intervention [(*13*)](https://paperpile.com/c/u4TPYy/Fp45) * Spatial scale as which the intervention is applied. | School-wide anti-bullying interventions are generally effective, but their impacts vary widely [(*12*)](https://paperpile.com/c/u4TPYy/XcBn). The frequency and duration of programs, and their ability to mobilise bystanders are seen as key determinants of effectiveness [(*12*)](https://paperpile.com/c/u4TPYy/XcBn). |
| Outcome measurement | What outcomes are measured and how they are measured | * Metric measured [(*6*)](https://paperpile.com/c/u4TPYy/gPod) * Method used to measure outcome [(*14*)](https://paperpile.com/c/u4TPYy/m69B) * Timing of measurement after intervention * Spatial scale at which outcome is measured | Using only the abundance of target invasive species as an outcome measurement ignores the fact that native species often do not recover abundance/diversity following invasive management [(*15*)](https://paperpile.com/c/u4TPYy/QQ5o). |

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In addition to the problems relating to relevance, there are sometimes multiple syntheses on a given topic, resulting in research waste [(*1*)](https://paperpile.com/c/u4TPYy/anGy). At the same time, reviews can become out-of-date quickly due to the rapidly increasing number of research papers published every year, potentially resulting in incorrect estimates of intervention effectiveness [(*19*)](https://paperpile.com/c/u4TPYy/06kd). These problems were brought into stark focus during the initial period of the COVID-19 pandemic [(*2*)](https://paperpile.com/c/u4TPYy/KUoP). The rush to synthesise evidence in order to inform policy resulted in the production of nearly 9,000 systematic reviews related to COVID-19 [(*2*)](https://paperpile.com/c/u4TPYy/KUoP). However, many of these syntheses repeated similar syntheses - there are more than 100 on hydroxychloroquine - and due to the massive number of clinical trials being published almost all of these are now out-of-date [(*2*)](https://paperpile.com/c/u4TPYy/KUoP). This appears to be generally true for systematic reviews in other fields. For example, approximately a quarter of systematic reviews in internal medicine are out-of-date within two years of publication [(*3*)](https://paperpile.com/c/u4TPYy/qrIz). One solution to the problems of production of multiple reviews and reviews becoming out-of-date is to have an online platform that provides details of existing and ongoing evidence syntheses that can also be updated to create ‘living reviews.’

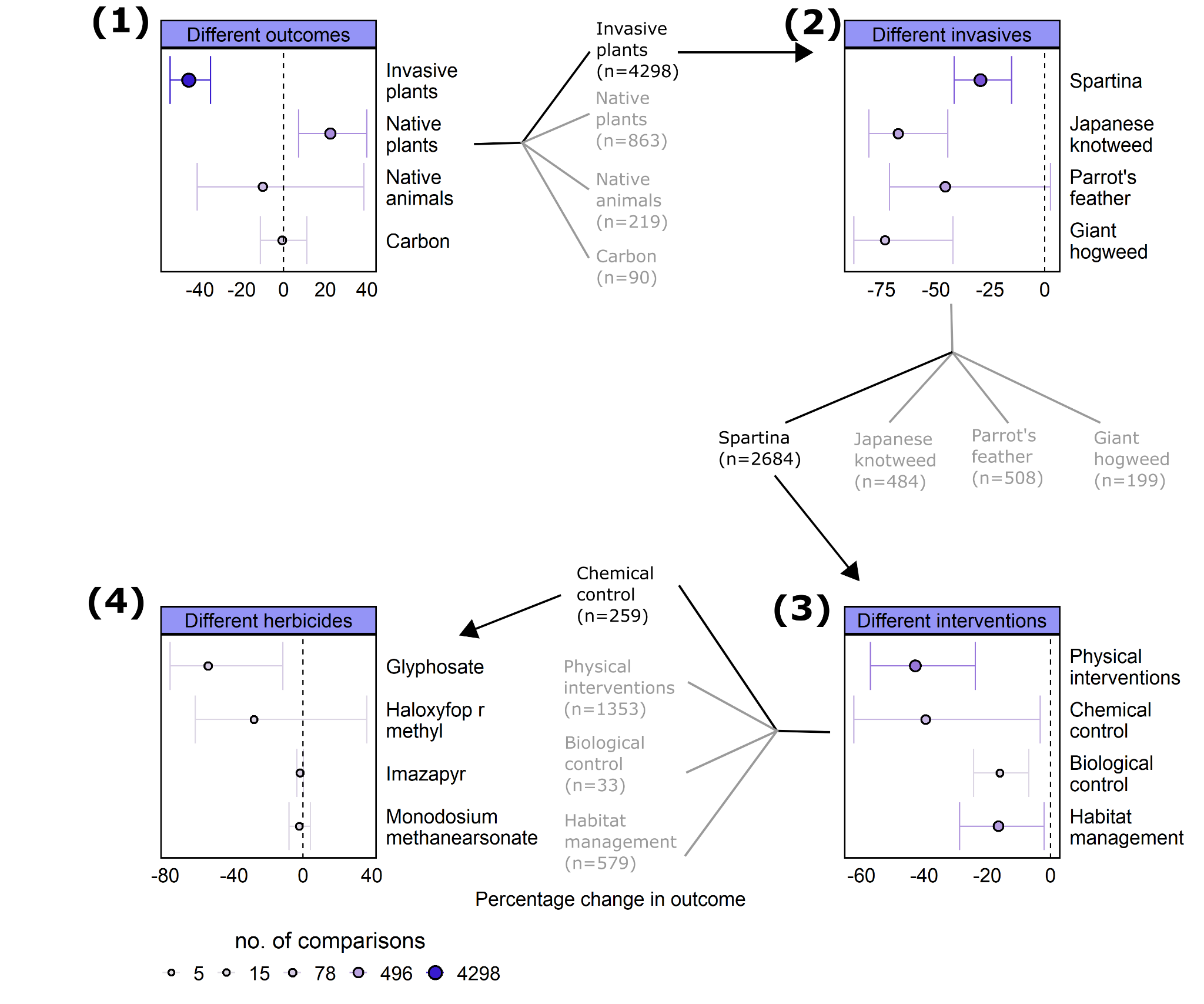
## Supplying relevant, up-to date evidence

To provide access to the highly-relevant and up-to-date evidence that practitioners and policymakers need, we believe there is a need for a new method of evidence synthesis that builds on advances made in systematic review. Such a method should allow users to explicitly define their context in terms of the setting, target population, intervention delivery, and outcome measurements (as detailed in Table 1), thus allowing users to navigate the existing evidence base. This method should allow decision-makers to address a wide range of questions while allowing for flexibility relating to different contextual factors. Below we present 'dynamic meta-analysis' as a novel method of evidence synthesis. This method uses systematic review methods to collate evidence combined with an interactive web app. The key difference between dynamic and traditional meta-analysis is that dynamic meta-analysis allows users to filter and weight evidence depending on their interests to produce tailor-made analyses (see Figure 1 for an overview).

To facilitate access to highly relevant evidence, we have developed a proof-of-concept of this idea in the form of a website and interactive tool called metadataset ([www.metadataset.com](http://www.metadataset.com))[(*20*)](https://paperpile.com/c/u4TPYy/ozus). The database currently contains data from primary studies on agricultural interventions (that seek to increase yields of target crops or reduce their negative environmental impacts) and invasive plant management (that seeks to reduce the abundance or occurence of problematic plants) that were compiled using standard systematic review methodologies. We are expanding the database.

Figure 1 shows the path a user might take to better understand, in this example, the impacts of different types of invasive plant management, with a particular focus on controlling an invasive plant species in the genus *Spartina* (cordgrass). This path is represented by the black line and arrows in Figure 1. Meta-analysis can produce different types of results, but here we used percentage change of the outcome measures, derived from the log response ratio effect size[(*21*)](https://paperpile.com/c/u4TPYy/SJLQ). For example, in the meta-analyses in Figure 1, after looking at the impacts of management on multiple outcomes (Figure 1, Box 1) the user has selected to look at the outcome for the abundance of invasive species (Figure 1, Box 2), is just looking at Spartina species (Figure 1, Box 3), and is looking at chemical control and comparing different herbicides (Box 4). The final analysis (Figure 1, Box 4) shows that Spartina abundance was reduced by 55% (across 11 studies with 78 comparisons) when glyphosate herbicide was used, but was not significantly reduced when other herbicides were used. This is just one route that could be taken in analysing outcomes, with users able to choose the route that interests them most (see the caption of Figure 1 for more detail). For example, another reader may wish to look at management impacts on carbon storage or the consequences for native species, or just look at studies in North America, or just look at studies concerning a specific Spartina species. Indeed, for an analysis of this sort a user, using our current data on invasive species, could potentially decide to run 98 different meta-analyses.

In addition to allowing users to filter the outcomes and interventions that are of most interest to them, the system also allows users to either filter out studies that are not relevant to their context or recalibrate study weights so that those with higher relevance contribute more to meta-estimates [(*16*)](https://paperpile.com/c/u4TPYy/2gKK). For example, a user may be interested in evidence from a particular geographic region or may wish to only look at studies that used the most robust methodologies. Thus, users can identify studies with the most relevant features, with results that are likely to transfer relatively well to their own context. Doing this in a dynamic way using an online interactive tool means that users can customise the analysis to their specific context rather than relying on a static systematic review which may not address the context in which they are interested.



**Figure 1** - A typical workflow of an analysis on metadataset. Each box represents a separate meta-analysis and the lines between represent the filtering process of selecting different populations, species, and interventions. Point size and colour are indicative of the number of comparisons used for each estimate. Labels on y axis refer to comparisons made at each level of meta-analysis. Branches between boxes represent potential ways of filtering the data, with the chosen route given in black, n refers to the number of pairwise comparisons for each branch. In plot 4, the meta-analysis reports data on the effectiveness of different methods of chemical control for *Spartina* on the abundance of the *Spartina*, but could equally show different methods of biological control for Parrot’s feather, etc.

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Not only does evidence synthesis vary in its relevance to decision-makers, but it can quickly become out-of-date. One solution to these problems is the use of ‘living reviews’ in which the evidence base is searched and regularly updated as new studies are published. This approach is rapidly gaining acceptance in healthcare and we think that it has great potential in other mission-driven fields.The tool we have designed allows for the production of living reviews by enabling addition of data from studies as they are published. In addition, by providing a repository for the data underlying systematic reviews of interventions, our tool makes it clear which topics have been covered or are in the process of being covered. This reduces the chances of multiple reviews of a topic being undertaken.

We suggest that dynamic meta-analysis presents an exciting new direction for evidence synthesis and decision-making - as demonstrated by our above example for the invasive plant species *Spartina.* This approach has the potential to provide practitioners and decision-makers with quick and easy access to an up-to-date and relevant overview of evidence for almost any mission-driven discipline. Dynamic meta-analysis may be particularly useful for complex interventions delivered through multifaceted programs since the results of these studies are perceived to be very context specific [(*22*)](https://paperpile.com/c/u4TPYy/1nDG). Though our recent focus has been agriculture and nature conservation, we suggest that dynamic meta-analysis would be useful in other mission-driven fields such as public health, development, and education. One example of a situation in which our approach may be useful is assessing anti-bullying campaigns in schools - the results of which appear to vary widely depending on their frequency and duration as well as their ability to mobilise bystanders to bullying [(Table1; *12*)](https://paperpile.com/c/u4TPYy/XcBn/?prefix=Table1%3B%20). Dynamic meta-analysis would allow a decision-maker to explore how the effectiveness of anti-bullying campaigns varies due to different contextual factors in a user-friendly, accessible format.

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**Realising the potential of dynamic meta-analysis**

Although we think that dynamic meta-analysis is a powerful tool, we also acknowledge that there is much work to be done, including by us, if its potential is to be fully realised. In the short-term, there are two needs: (i) expand our database to cover more topics relating to biodiversity conservation, thereby allowing more powerful analyses on a wider range of topics; and (ii) refine the tool through user testing in order to make it easy to use. We also call on funders to invest in the collation of data to enable dynamic meta-analysis. In the longer-term, in order to maximise the value of dynamic meta-analysis, and evidence synthesis in general, we think that there is a need for increased funding of roles in which people can act as intermediaries between research and policy, sometimes termed evidence bridges or knowledge-brokers [(*23*)](https://paperpile.com/c/u4TPYy/QYhC). People in these roles could be trained to use dynamic meta-analysis and related tools to produce robust analyses that can be used to inform practice and policy.

Dynamic meta-analysis presents some problems. Of foremost concern is the inappropriate use of analyses to find statistical significance for a particular result, termed ‘p-hacking’ [(*24*)](https://paperpile.com/c/u4TPYy/5CwU). This could result from individuals selecting evidence that supports a specific agenda or searching for significant results for publication. However, we suspect that this is unlikely to present a major problem for our tool for three reasons. First, we think that many decision-makers are not seeking to support a particular agenda or looking for significant results but are simply trying to find an answer to a question. Second, our tool allows users to provide a URL link to the analysis that they carried out - allowing for other users to see exactly how the analysis was carried out. These other users could then repeat the analysis, modifying settings as they see fit, to examine whether reported analyses are robust to other evidence, a major advantage over static meta-analysis. Third, if this approach becomes more common, then the skills needed for analyses are likely to become more common within the practitioner community - leading to higher quality analyses.

We also acknowledge that dynamic meta-analysis is not necessarily useful in all circumstances. For example, we think that co-designed systematic reviews are extremely useful for informing expensive, large-scale policy decisions where the costs of mistakes are high [(*25*)](https://paperpile.com/c/u4TPYy/Rkqj). However, most decisions are relatively small, local decisions, made by a small team, where co-designed systematic reviews are unlikely to be cost effective [(*25*)](https://paperpile.com/c/u4TPYy/Rkqj). In these cases in particular dynamic meta-analysis has the potential to provide rapid, quantitative answers, for problems where context is important and where decisions need to be made relatively rapidly, and costs need to be kept low [(*25*)](https://paperpile.com/c/u4TPYy/Rkqj).

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We envision a future in which dynamic meta-analysis can be used to address questions when answers are needed rapidly or where resource constraints preclude co-produced systematic review. To achieve this, we call on policymakers and funders to prioritise the training and hiring of knowledge-brokers who act as intermediaries between researchers and policymakers. If well implemented, this step could aid society in overcoming many of the pressing global-scale challenges that require the application of interventions. Although these challenges occur at the global scale, their solutions must be delivered at national or subnational scales. We believe that synthesis that generates locally relevant evidence is one of the many steps needed to ensure this.

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