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How research reproducibility challenges librarians' skill sets. A French librarian's perspective

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Similar to their colleagues from other countries, French academic librarians are involved in the promotion of data management plans and FAIR (Findable, Accessible, Interoperable, Reusable) principles, as first steps towards more transparent research. But reproducible research requires one to dive into a wide range of subjects (*e.g.*: statistics, study design, scientific computing) that are quite far from a French librarian's daily practices and/or initial training given that most have a degree in literature or history (1). Librarians do have technical expertise, but horror stories (2) pinpoint the fact that even seasoned academics and data science experts seem to lose track of current techniques, after decades of dizzying technical and methodological mutations. In such a context, what could be the added value of librarians? To what extent do they have to plan a mutation of their skill sets? See summary in Table 1.

Classy but trendy: information skills at the forefront of reproducible research

Statistical and computational skills are key components (3–6) of more reproducible research. However, is there room for people who are not familiar with the command line or statistics methods? Of course, some librarians have developed data management skills. Nevertheless, the stakes of traceability also bring back to the forefront a librarian's traditional skills. In more fundamental disciplines, the reproducibility of research is seen less as the ability to obtain similar results than as the capacity to track back the argumentation. In this perspective, the management of references and more particularly the follow-up of retracted articles play a major role. Data management skills thus remain central, especially when it comes to taking advantage of tools that automate tasks, such as Zotero.

Indeed, many services focusing on information needs can be targeted in the reproducibility perspective. Practices such as systematic review (7) can also help to limit the impact of biases (*e.g.*: selective reporting, confirmation bias). Information addressing a specific research question is exhaustively collected by using pre-established and standardized eligibility criteria (*e.g.*: type of method applied, source of funding, measurements obtained, etc.). The data are then synthesized with or without the use of statistical methods. Systematic reviews are common in health sciences (8) and through adaptations, their use could be extended to other fields as they can limit the impact of bias toward positive outcomes (9): the published results represent only part of a corpus composed of different types of data, including grey literature (*e.g.*: reports, unpublished research outputs, technical reports, etc.) .

The standardization of information-gathering methods and a broadening of documentary sources contribute to the transparency of research. However, not all editorial forms benefit from the same visibility due to research evaluation criteria and the policies of traditional publishers who value the article in its canonical form. Thus, replication studies (10–12) or forms of pre-registration (13–15) [*i.e.*: registered reports, registered replication reports (16)] deserve greater publicity. For librarians, it doesn't mean to promote these sources without nuance as pre-registration is a subject of debate (17), but to synthesize the ins and outs, and to present the platforms for where to find them (*e.g.*: Open Science Framework). In their field, librarians can thus participate in limiting the "file drawer effect" (5,9,18). The file drawer effect can be defined as a bias that leads researchers to put in the "drawer" anything that doesn't fit into the criteria of traditional editors who favor

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positive and catchy results: “Modern science’s professional culture prizes positive results far above negative results, and also far above attempts to reproduce earlier research. Scientists therefore steer away from replication studies, and their negative results go into the file drawer.” (5)

Decathlete fatigue: challenges of skill specialization

Beyond interdisciplinary stakes, the advent of data-driven research and the issues of research reproducibility have accentuated the need for a plurality of expertise in teams. Of course, having a basic knowledge of computer science and/or statistics is of major interest, but the level of expertise to be achieved is such that the competency should no longer be understood at the level of an individual, but at the level of a whole team, according to Wessel (19) : “Statistical illiteracy among researchers is one of the reasons why psychology as a whole is in trouble. The solution is thought to lie in educating people about statistics. Of course, furthering a basic understanding is important, but investing in statistical skills at an individual level is not the ultimate solution. There is a limit to what individual researchers can do.” Leek (20) also emphasizes the need for specialists to ensure appropriate use of statistical methods: “Since most people performing data analysis are not statisticians there is a lot of room for error in the application of statistical methods. This error is magnified enormously when naive analysts are given too many ‘researcher degrees of freedom’.” Moreover, even the choice of the method to be applied is arduous for a non-specialist according to Wilcox and Rousselet (21): “But for the non-statistician, the vast array of new and improved techniques for comparing groups and studying associations can seem daunting, simply because there are so many new methods that are now available.”

At the same time, thanks to adapted graphical user interfaces, tools that can be used without advanced technical skills have been developed. But the use of these tools doesn’t solve the problem of the reliability of the results. According to Plesser (22), methodological questions are obliterated because they are hastily delegated to tools: “Since digital computers are exact machines, practitioners apparently assumed that results obtained by computer could be trusted, provided that the principal algorithms and methods employed were suitable to the problem at hand. Little attention was paid to the correctness of implementation, potential for error, or variation introduced by system soft- and hardware […].” In addition, these tools, which are suitable for non-specialists, are still part of broader and more complex ecosystems, the full control of which requires an advanced technical background.

A patchwork is not a canvas: disconnected expertises

Bringing different expertises together responds to immediate functional needs and also allows for a richer approach to the research question, according to Munafò and his co-authors (14) : “This also brings greater scope for multiple theoretical and disciplinary perspectives, and a diverse range of research cultures and experiences, to be incorporated into a research project.” Yet, as Bammer (23), Brown (24), and Jang (25) consider, the juxtaposition of skills doesn't always ensure better results because it can also be a vector of dissonance.: “[…] cultural differences between team members can lead to inconsistent norms and conflicting assumptions, making it difficult to access and synthesize the diverse knowledge they hold.”

If left unmanaged, interdisciplinary and inter-professional collaboration can increase the risk of error, as Yarborough and co-authors note (26): “Indeed these errors [study design and data analysis errors] are likely to increase due to trends in current scientific practice, particularly the growing size and interdisciplinarity of investigative teams.” Non-reproducibility has both technical and methodological causes and stems from organizational and behavioral issues. Increased segmentation of work between experts as well as the reinforcement of the dynamic of specialization do not lead to more reliable research. Leonelli (27) considers it to be an aggravating factor. When a plurality of actors are involved, *a fortiori* during the complex process of analysis, clearly defining responsibilities is challenging: “[A plurality of actors results in] a general increase in the complexity and scale of experiments and related statistical analyses of results, with increasing specialization and division of labor resulting in lack of clarity around who is

actually responsible for quality checks." Yarborough and his co-authors (26) also point out the increased risk of errors resulting from the division of work and expertises: "[…] Because they require divisions of labor and expertise, such collaborations create fertile ground of producing unreliable research."
As noted by Deardorff (28), the distribution of expertise engages researchers to be accountable for steps carried out by others: "For some researchers, this meant taking ownership of a step that had previously been done by a collaborator". But even more than in the past, identifying the parameters that impact the results can be tricky (4), even at the team level: "When closely scrutinized, a scientific study or experiment may be seen to entail hundreds or thousands of choices, many of which are barely conscious or taken for granted. […] An investigator may or may not realize when a possible variation could be consequential to the replicability of results."
Moreover, the issues of research reproducibility accentuate the need for a reinforced dialogue as they question what appears to be self-evident: what is a result? What are we trying to reproduce: a model, a process, an object? The variety of meanings of the phrase "reproducible research" as analyzed by Barba (29) emphasizes the need for contextualization. Therefore uncovering the cultural gaps inherent in professional and disciplinary practices isn't considered by the Committee on Reproducibility and Replicability in Science (4) as a futile effort: "Despite efforts to coalesce around the use of these terms, lack of consensus persists across disciplines. The resulting confusion is an obstacle in moving forward to improve reproducibility and replicability."

The process of "cultural brokerage" at the service of interdisciplinarity?

The coexistence of different types of expertise can lead to an increased risk of errors insofar as the actors have their own norms, beliefs and hypotheses. Thus, Brown (24) mentions "substantial transaction costs" that come with interdisciplinarity. Of course, other parameters also affect the dynamics of a team (*e.g.*: the inadequacy of evaluation criteria, the legitimacy that each actor grants himself according to their place in the academic community, the stakes inherent in a career stage). But this contribution focuses on the issue of cultural heterogeneity within a group and the possible role of librarians.
According to Jang (25), a process of "cultural brokerage" can foster cohesion within a team: " Brokerage is typically depicted as taking place between actors who have no access to one another—for instance, at the intersection of organizational or professional boundaries." Thus, cultural brokerage is not about dividing tasks or directly transferring skills between actors, but about overtaking the hiatus in professional cultures. Jang distinguishes "cultural insiders", who share all or part of a team's knowledge, from "cultural outsiders", whose knowledge doesn't overlap with that of the group. Insiders act as translators (*i.e.* "resolving"); they are messengers (30). Outsiders connect team members by involving them in the process of capturing the group's tacit norms (*i.e.*: facilitating) (30); they don't directly provide an answer. Moreover, while cultural insiders may informally take on an intermediation role, outsiders need their assignment to be formally posed within the team to be able to fully play their role.

From "embedded librarian" to "cultural broker"

Because of their role in the academic community and the nature of their skills, librarians seem predisposed to engage in the process of cultural brokerage. Indeed, the well documented (31) concept of the "embedded librarian" already refers to the notion of an information professional integrated into a group of users, in a punctual or more perennial way, online or in a physical way. This consists of an in-depth and personalized documentary assistance, resulting from empathetic capacities and knowledge of the treated topic. The concept of "embedded librarian" isn't new, but this role can evolve towards that of a "cultural broker".
Should librarians aim to become cultural insiders? Not necessarily, because the contribution of outsiders is equal or even superior to that of insiders (25,30). This finding is surprising because it's precisely the perception of their expertise that penalizes the insiders. Indeed, outsiders have the advantage of being viewed as neutral third parties, less inclined to judge than insiders. In addition, given their greater proximity to group members, the insiders' clarification efforts may be perceived as unnecessary. Added to this, the

inclusion of outsiders would secure the group's cohesion in the long term (30): “Cultural outsiders may be particularly valuable in teams with long time horizons, where team viability is crucial.” Indeed, outsiders educate teams to enact internally the cultural brokerage process.

Toward a “blameless *post mortem* culture”: enabling supportive work environments

Data science standards have been drastically raised under the pressure of reproducibility challenges, but the acquisition of technical knowledge is not only a technical issue. The point is less to seek to achieve the level of expertise to deal with the issue than developing dialogue skills. Training eases the dialogue between researchers with different technical levels, according to Deardoff (28): “[...] the workshop had helped demystify a complicated topic. […] [Researchers] felt more comfortable talking about programming with their collaborators […].” In addition to traditional training, librarians can create or support communities of practice such as "ReproduciliTea" (32), “The Turing Way” (33). Activities can be designed by type of needs, not just by level of technicality: for example, data engineers' concerns are more focused on infrastructure and IT equipment. Data analysts and machine learning engineers tend to focus on front-end issues (*i.e.*: analysis and presentation of results). A “Reprohack” is a relevant way to favor dialogue skills (34). Their expertise in scientific monitoring and information retrieval will help librarians to identify experts who can conduct these activities.

Actions based on collaborative practices (*e.g.*: hackathons, peer programming sessions, code reviews, sprints), contribute to initiating a broader dialogue (35–37). For instance, by easing capturing and codifying tacit knowledge, a book sprint (38–41) enables cultural brokerage. In a couple of days, a group of authors supported by a facilitator writes a complete book from scratch [*e.g.*: book sprints organized by librarians (42,43)]. According to Baker and her co-authors (38), “[…] the book sprinting process, by stressing the collaborative aspects, materializes the being-together, working-in-tandem, sharing and intersubjective exchange of ideas, but also written text, submerging authorship into a collective form of writing which is extremely powerful”. If the group of authors is homogeneous, the book sprint helps them to describe and synthesize their knowledge and the role of the facilitator is to introduce coherence (38) (*i.e.*: “extractive mode”). In contrast, when group members have little in common, the facilitator focuses on the emergence of new concepts and helps authors to put some distance from their existing practices (*i.e.*: “generative mode”). However, without prior analysis of the context, collaborative activities turn out to be counterproductive: a hackathon turns into an unhealthy competition, the pair programming session becomes an evaluation. Once again, neither the bringing together of actors nor the application of a collaborative method suffices to trigger the process of cultural brokerage and the added value of librarians lies precisely in their knowledge of the practices and norms of "academic tribes" (44).

The skills gap plays a role in group interactions but the problem has first a behavioral nature, as Varoquaux points out (45): “Inability to understand the others’ point of view, or to communicate ours, can bring in emotions. Emotions most often impedes technical communication”. But the emergence of a new ethos is a long term goal, hampered by academic culture as Herterich and her co-authors (46) point out: “Academics are pressured by this academic fallacy that they need to be brilliant at all aspects of the job, which means they are reluctant to share something they’re not brilliant at.” Therefore, enabling safe working environments should be a priority. It’s neither a luxury nor a fashion, and therefore Herterich and her co-authors (46) put psychological barriers and material constraints on the same level : “limitations on time, on resources, and on confidence”. Bishop (47) highlights the cultural change inherent in more open and transparent research: “As open science becomes increasingly the norm, we will find that everyone is fallible.” Therefore Parker (48) calls for a “blameless *post mortem* culture”. In this context, being seen as neutral third parties seems to be an advantage for librarians.

Conclusion

Reproducible research mobilizes a set of methods and techniques that are a priori far removed from the field of librarians. However, the dynamic of hyper-specialization that has been at work for several years now shows the

need for a form of cultural brokerage because the juxtaposition of expertise can accentuate the risk of errors. While librarians can place their more traditional skills in the broader context of reproducibility, they also have the opportunity to strengthen their connections with their users by moving from embedded librarian to cultural broker. The development of skills, especially computational skills, plays a major role, but not only on a technical level: it's also required for building consistency between stakeholders. Indeed, changes in organizational behavior call for deep cultural change. Therefore librarians can take advantage of the fact that they are seen as neutral agents by researchers. But they first need to be identified as potential collaborators. Thus, the question of visibility remains a major issue for librarians.

Table 1.

Challenges encountered by researchers, linked to the reproducibility of research	**Need**	**How librarians may support researchers**
Publication bias favor positive results	Broadening the diversity of sources .	Standardizing information gathering.
Emergent editorial forms may suffer from a lack of visibility among researchers	Getting familiar with these emergent editorial forms.	Summarizing the ins and outs of emergent editorial forms to feed the debate. Selecting platforms where this material is available.
Tracking retracted articles requires additional attention	Revamping source workflow of bibliographic records.	Training in the use of tools that automate the management of sources (ex: Zotero). Training in the methods.
Standards in data science required by reproducible research needs are so high that expertise needs to be distributed among a wide pool of actors. But the juxtaposition of expertise also increases the risk of errors.	Capturing tacit norms, beliefs and hypotheses from different stakeholders in order to lower the cost of these disconnected expertises.	Playing the role of "cultural broker": offering and/or supporting collaborative environments for researchers. As librarians may be seen as neutral third parties, they may play a positive role in the dissemination of methods and topics.
Transparency calls for disclosure, but cultural academic norms prevents researchers from moving towards a new ethos	Building inclusive and secure work spaces, developing soft skills that help nurture hard skills: expertise and performance may be threatened by a lack of *ad hoc* soft skills.	

Table 1: a non-exhaustive list of librarians' set of skills that could be relevant to address reproducible research challenges.

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