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Computational Stylistics

Abstract: Computational Stylistics (CS) is a field of enquiry that examines the forms, social embedding, and the aesthetic potential of literary texts by means of computational and statistical methods. Operating on larger data sets with more transparent methodologies, CS offers literary studies new scales of observation and new methods of interpretation, to test existing theories and form new ones. As in many data-driven fields, methods range across exploratory, explanatory, and predictive modeling, with important debates addressing the affordances and limitations of each. From its multiple heritages in authorship attribution, stylistics, and natural language processing, CS has evolved to tackle ever more ambitious theoretical questions, including style, genre, and epoch; literary topoi, plot, and character networks; narrative perspective, figure characterization, and emotion; gender, race, and social status; canonicity, literariness, and textual quality; and cognitive representations of word beauty, metaphor, and rhyme. Situated within the data sciences, CS comprises distinct knowledge domains, in which the affordances of the digital (method, medium) and the statistical interact with the epistemic to produce new knowledge at the analytic levels of "text," "context," "author," and "reader."

Introduction

Computational stylistics (CS)[1] is an emerging field that strives to model the multi-dimensional phenomenon of "literary discourse" by means of computational and statistical methods. Applying a data-driven paradigm, CS pursues both systematic and historical perspectives on a range of topics, such as fictionality and aesthetics, questions of cultural capital, prestige and inequality, and reader reception. It focuses on the forms, the content, as well as the social, cultural, and cognitive functions of literary texts embedded in social and historical context(s).

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[1] The term "computational stylistics" also points to advanced stylometry, specifically, a research group originally initiated by Maciej Eder, Mike Kestemont, and Jan Rybicki https://computationalstylistics.github.io/ The present paper maintains a wider definition, incorporating diverse approaches to literary phenomena with computational means, and putting emphasis on modeling the readerly dimension of literary discourse.

CS is situated within the larger frameworks of data science and digital humanities, capitalizing on new opportunities brought by the large-scale digitization and curation of textual cultural heritage (HATHI, German Text Archive, wikidata, Gutenberg etc.), born-digital data (e. g., social reading and writing platforms), and open-linked data (e. g., national libraries, europeana, wikidata). Using software for text processing, machine learning, visualization, and statistics (e. g., Python, R, Java), CS applies evidence-based, data- and variable-driven techniques to explore datasets, establishing principles that explain the occurrence of textual and contextual patterns and their relationship with potential formal-aesthetic, social, and cognitive functions of literature. In this paper, these perspectives are summarized broadly as "formalist," "social," and "cognitive" approaches to the study of literature.

The most pertinent data-driven disciplinary traditions for CS are stylometric authorship attribution studies (Juola, 2006),[2] corpus linguistics (Firth, 1957; Sinclair, 1991), corpus stylistics (Mahlberg, 2013), natural language processing (Manning & Schütze, 2010), humanities computing (Hockey, 2004), cultural sociology (Underwood, 2017), empirical reader response theory (Hakemulder & van Peer, 2015), and neurocognitive and computational poetics (Jacobs, 2015a; 2017, 2018a,b, 2019; Schindler et al., 2017). While CS is grounded in data-driven text analysis, research directions are emerging that connect textual modeling with reception and contextual data, such as online book ratings, demographic data, or social and economic indicators.

Despite its clear "empirical" orientation, CS notably includes approaches that emphasize "hermeneutic" processes, i. e. interpretative and subjective dimensions modeled within a computational approach (Herrmann, 2019). One of the challenges for the future of CS will be integration of these different epistemic traditions, with clearer attention paid to the relationship between research aims and research methods. Rather than argue for a single best-model of research practices, our vision for the field is deliberately heterodox when it comes to theory and methodology.

Like literary studies at large (Hayot, 2016; Jauß, 1970), CS has a strong historical orientation, epitomized by the socially inclined "distant reading" of world literature (Moretti, 2000), and has long reflected upon questions of periodization (Dimock, 2006; Underwood, 2013). Moving beyond the limited purview of a single researcher's reading knowledge (Crane, 2006), transforming literary texts and contextual information into data allows for the scalable observation of historical frameworks. Through this, existing temporal frameworks can

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2 See also the stylometry bibliography https://www.zotero.org/groups/643516/stylometry_bibliography

be re-assessed, and new ones discovered, using longer arcs (Underwood, 2019) as well as potentially new temporal sub-groupings within those frameworks (Hughes et al., 2012).

Contributions to computational stylistics can be found in journals such as *Digital Humanities Quarterly (DHQ)*, *Digital Scholarship in the Humanities* (formerly *Literary and Linguistic Computing*), the *Journal of Cultural Analytics*, *ZfdG – Zeitschrift für digitale Geisteswissenschaften,* as well as the proceedings of the Association of Computational Linguistics's (ACL) *Workshops on Computational Linguistics for Literature,* now known as the *SIGHUM Workshop on Computational Linguistics for Cultural Heritage, Social Sciences, Humanities and Literature*. Additionally, in 2017, the *Alliance of Digital Humanities Organizations* (ADHO) formed a special interest group (SIG) *Digital Literary Stylistics* (SIG-DLS) and March 2021 saw the start of the multilateral *Computational Literary Studies Infrastructure*, funded by the European Commission.[3]

Our introduction to CS strives to provide an overview of emergent research questions that are being asked in this diverse and quickly-developing field, as well as the related theories, concepts, and methods that are evolving to address them. Rather than focus on "how-to" issues related to computational stylistics, this chapter will give readers entry into the multiple, robust strands of research that are currently available. While there are numerous handbooks and resources that focus on the application of computational text analysis (e. g., Arnold & Tilton, 2015; Baayen, 2008; Gries, 2013; Jockers, 2014; Karsdorp, et al. 2021; Piper, n. d.; Silge & Robinson, 2017, 2020), a good overview of the impact that CS is making on our understanding of literary discourse is lacking.

Towards a Map of the Field

CS provides ways for exploring, building, and testing theories of "literature" across a wide array of text-, context-, author-, or reader-oriented approaches. We group our review into the three larger categories of (a) formalist, (b) social, and (c) cognitive approaches, although it is important to emphasize how these necessarily blend into one another. Each of these three groups also comprises systematic as well as historical approaches to the study of literature. Indeed, the question of historiographic modeling and periodization – of how to think about literary change – is an emerging field in its own right (Jannidis & Lauer, 2014; Piper 2018, pp. 94–117; Underwood, 2019).

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3 http://dls.hypotheses.org/; https://cordis.europa.eu/project/id/101004984

(a) Formalist approaches derive their primary focus from the fields of *poetics* and *aesthetics* and concentrate on understanding the distinctive features and structures of literary works. Such approaches may ask about the manner of writing that constitutes literariness (Jakobson, 1987), poeticity (Salgaro, 2018), fictionality (Piper, 2018, pp. 94–117), novelty (McGrath et al., 2018; Liddle, 2019), or literary quality (van Dalen-Oskam, 2014; van Peer, 2008). Or they may concentrate on better understanding the nature of genres (Underwood, 2016; Jannidis et al., 2019; Wilkens, 2016), periods (Jannidis & Lauer, 2014), or authorial style (Burrows, 1987a; O'Sullivan et al., 2018; Tuzzi & Cortelazzo, 2018).

(b) By contrast, social approaches pay greater attention to extra-textual contexts, i. e. types of social practice across communities. This line of research has a long tradition leading back to Herder, de Stael, and other thinkers from the turn of the nineteenth century for whom literature was seen as a primarily historical and societal affair. Building on Bourdieu's (2000) theories of social distinction and cultural capital, critical theory (Eagleton, 1991; Lukács, 1965; Williams, 1980), and new historicism's emphasis on the power of social context (Gallagher & Greenblatt, 2001), questions in this vein inquire into the observable textual and contextual factors behind notions of "distinction," "canonicity," and "prestige," and thus social, political, and economic power. A related strand of research draws on the robust work of book historians (Darnton, 1982) to focus on reader behavior and reading communities (Fish, 1980). Here the goal is not to infer "intrinsic" literary qualities or values, but to assess the discursive priorities of different reading communities and to understand these as part of larger social fields of interaction.

(c) Finally, cognitive approaches tap into the "cognitive" branch of aesthetics and stylistics (van Peer, 1986), the psychology of literature (Groeben, 1972), and reader response (Fish, 1980). They aim at integrating the insights from the fields of computational text analysis with knowledge of readers' embodied affective and cognitive systems. Studies examine features of literary texts and their effect on readers, measured by information from surveys, real-time data, and other types of reader response data.

This taxonomy is offered for heuristic purposes only. Given the field's growing diversity and complexity, it may provide a useful framework for orienting new and existing scholars within the field. Nevertheless, we are aware that it necessarily omits a great deal of the actual overlap, differences, and interconnection between these various approaches.[4]

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4 Identifying a "primary orientation" of literary studies, Köppe and Winko (2013) suggest a similar heuristic grouping into one of the main categories "text," "context," "author," and "reader-orientation," adding the caveat that "Verwandtschaften und Unterschiede zwischen

The primary objective of this overview is to emphasize that a computational approach to literary study does not prescribe any single theoretical axiom or type of question. For example, for a topic like "literary quality," approaches can be predominantly formalist (...do high-brow books share *observable textual features* when compared to low-brow books?), social (...does literary evaluation change historically as a function of predominant *national ideologies*?), or cognitive (...do *readers' appreciation* of one and the same text vary, depending on its presentation as "high-," "middle-," or "low-brow"?). While these frameworks are as broad as possible, within such a quickly expanding field, they will necessarily overlook important work. Our references, then, should be seen as potential entry points for future study. We conclude by identifying three primary challenges that are high priorities for future research, with a focus on data collection, methodological validation, and interdisciplinary integration.

Formalist Approaches

Style

Style is, broadly speaking, "the manner of writing" or "an ensemble of formal features" (see Herrmann et al., 2015). Any formally oriented study of literary language use thus necessarily has a "stylistic" dimension, with forms and patterns taken as indicative of higher-level textual and contextual phenomena. For example, as questions about style often also address meaning, stylistic patterns can be approached as potential textual correlates of cognition and emotion – in authors as well as in readers.

Classical stylometry has established that the most frequent words, especially function words – such as *the*, *of*, *in*, etc. – are the most reliable parameters for measuring stylistic similarity and distinction (Burrows, 2002). Capitalizing on these findings, "non-canonical stylometry" applied to literary texts experiments with a larger range of features (including content words and units beyond the word). Here, style is approached descriptively as the linguistic particularity of some agency, typically the author.

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den einzelnen Ansätzen bleiben ausgeblendet, und überdies liegt der Unterscheidung kein trennscharfes oder einheitliches Klassifikationskriterium zugrunde" (p. 288). ["relationships and differences between the individual approaches are not taken into account and, moreover, the distinction is not based on a clear or uniform classification criterion," our transl.]

The authorial signal is complemented by studies assessing signals of genre (Erlin, 2017; Hoover, 2007; Jannidis et al., 2019; Piper, 2015; Underwood, 2016; Wilkens, 2016), epoch (Jockers, 2013, Chapter 6; Jannidis & Lauer, 2014), and fictional character (Cheng, 2020; Jacobs, 2019; Kraicer & Piper, 2019; Piper, 2018; Underwood et al., 2018). To establish particularity and specificity, a wide array of descriptive and multivariate statistical techniques can be applied, normally using some type of reference "norm" (corpora representing other authors, periods, characters, etc.).

An important insight is that there is no "stylistic fingerprint" understood as unequivocal attribution of texts to authors, genres, epochs, or characters, but rather, one works with probabilistically determined potentials. Stylometry continues to be used for literary attribution and description (e. g., Schöch, 2014, on French crime novels; Tuzzi & Cortelazzo, 2018, on Elena Ferrante). Current studies increasingly combine explanatory with exploratory and quantitative with qualitative approaches. For example, probing the idea of Robert Musil's stylistic indeterminacy, Rebora et al. (2018) report detailed probability measures of authorship of Musil himself, but also of a so far unconsidered candidate. A subsequent descriptive "specificity analysis" (using Craig's and Eder's Zeta; Schöch, 2018) found authorial differences in style and content between the two authors with a high degree of interpretability (for a similar approach to Goethe's authorship, see Kestemont et al., 2019).

Within the field of corpus-based literary studies, Mahlberg et al. (2013) address the narrative phenomenon of "suspended quotation," an interruption of a fictional character's speech by the narrator. Assessing lexico-grammatical patterns in the work of Charles Dickens, they find relationships between suspended quotation and body language presentation across different literary texts and time. "Close reading with computers" (Eve, 2019) is another research trend, pursuing computational micro-analysis by quantitative comparison within small corpora or single literary works, e. g., Joseph Conrad's *Heart of Darkness* (Stubbs, 2005).

CS also offers an interesting perspective on updating the author-oriented strand of stylistic criticism, using automatic word classification along psychologically meaningful dimensions (e. g., cohesion, time orientation, and sentiment). In this *psychostylometry*, with due caveats, proxies of psychological states and traits of literary authors can be constructed through analysis of words referring to emotions, bodily states, and cognitive processes (Herrmann, et al., in preparation). Specifically, function words (conjunctions, prepositions, pronouns) can reveal much about psychological and social processes represented linguistically, including emotional state, cognitive complexity, and sociability (Tausczik & Pennebaker, 2010). There is considerable potential in a com-

putational-stylistic approach within a digital *critique génétique*, operating on digitized (Hulle 2018) or on born-digital (Ries, 2018) "dossiers."

Literariness and Fictionality

Since Aristotle, philosophers and philologists have attempted to understand the distinctions between the communicative and creative use of language (Aristotle's *legein* vs. *poiein;* see Genette, 1983; Hamburger, 1973). Research in this vein asks what textual features can be related to the effects ascribed to literary language (Leech & Short, 2007; Spitzer, 1928) and whether there are distinctive qualities of literariness or fictionality that transcend time and space.

Depending on the particular theory, "literariness" and "fictionality" can overlap, complement, or even contain each other. For example, the CS predecessor Russian formalism aimed at articulation of a general formal inventory of "what makes a given work a *literary* work" (Jakobson, cited by Eikhenbaum, 1971, emphasis in the original). This encompassing notion of "literariness" largely coincides with a formalist approach to "fictionality," as an intentionally signaled, communicated *invention* (Zetterberg Gjerlevsen, 2016), or it can predominantly refer to "artistic usage of language" (Hakemulder et al., this volume), i. e. *creatively foregrounded* language use is likely to catch readers' attention.

Underwood and Sellers (2012) provided one of the first CS studies of a general "literariness" signal on a large text (English-language) corpus through time, pointing out that the internal variation of literary genres complicates this endeavor (see also Heuser & Le-Khac, 2012). Addressing "fictionality" from a theory-driven approach, Piper (2018, pp. 94–117) examines several fictional and non-fictional data-sets across two languages from the nineteenth century to the present. He tests three hypotheses, namely "negativity of literature" (i. e. there are no distinguishing features of literary texts); "referential priority of the novel" (i. e., what most defines novels over the past two centuries is their investment in realism); and "periodization of literature" (i. e., the optimal way to describe the historical evolution of fiction over time is as discrete clusters or periods). Based on his findings, Piper rejects all three hypotheses and proposes three alternative data-driven theories of fiction: the legibility, immutability, and sensibility hypotheses. Further work is needed to test these and other hypotheses on more data and across more languages.

The data-driven methods of CS allow researchers to test, rather than simply theorize, the various stylistic features that distinguish literary / fictional from non-literary / non-fictional discourse. Doing so, researchers can begin to better understand the aesthetic qualities underlying the social distinctions and social

functions of literary texts, moving away from normative valuation to more descriptive models of social and human behavior.

Metaphor

Metaphor, defined as "giving the thing a name that belongs to something else" (Aristotle, *Poetics*, Ch. 21, 1457b1-30), is widely considered a signature feature of literature. Metaphorical language (including idioms, personification, and similes) caters to vivid imagery, creative re-contextualization, and representation of subjective thought (Caracciolo, 2016; Semino & Steen, 2008). Metaphoric language corresponds to figurative processes underlying domains of human experience in everyday discourse (Fauconnier & Turner, 2008; Lakoff & Johnson, 1980) and literature (Lakoff & Turner, 1989).

The two key tasks of computationally identifying and interpreting metaphor still pose major methodological challenges, and thus CS revolves around methodological research questions, as well as implementing models of metaphorical thought and language in formal systems. Specifically, natural language processing (NLP) is dedicated to the automatic detection of metaphorical expressions, but also to modeling how world knowledge – which according to conceptual metaphor theory is necessarily embodied – may be represented in a computational metaphor-processing system (Veale et al., 2016).

Reliable detection, whether manual or automatic (Shutova 2017; Steen et al., 2010a), is a precondition for answering questions about metaphor distribution across genres, authors, and time (Semino, 2008; Tissari, 2016).[5] While empirical research has highlighted the ubiquity of metaphor, CS studies have begun asking questions about the specificity of *literary* metaphors, in terms of distribution, semantic and syntactic features, and aesthetic functions.

Examining the fiction sample of the VUAMC,[6] which covers the full range of conventional and creative metaphor use in contemporary English, Dorst (2015) finds an average rate of 11% metaphor-usage, which is lower than that of news discourse, but higher than that of spontaneous conversation. Scrutinizing a sample of beginning sections of German fiction (1880-1926), Herrmann (2018) reports an average of 14% metaphor-usage, with realist and "high-brow" texts

[5] In addition, there is a growing number of automatic, i. e., rule-based (Neuman et al. 2013), unsupervised, or deep-learning approaches to metaphor detection (see Tanasescu et al., 2018).
[6] The hand-annotated *VU Amsterdam Metaphor Corpus* (VUAMC, Steen et al., 2010b), compiled from the British National Corpus. Its "fiction" sample draws on late twentieth-century British middlebrow novels.

showing fewer metaphors and popular and "fashionable" texts showing an above-average tendency. As to temporal variation, she reports fewer metaphors for texts after 1920. Implementing the *English Historical Thesaurus*, Anderson et al. (2016)[7] ask more generally how particular metaphors developed over the centuries, to which text-external factors they respond, and which domains of experience are most prominent in metaphorical expressions (for entropy-based metaphoric change detection in German, see Schlechtweg et al., 2017). Tending to conceptualizations of the reading process in online book reviews, Herrmann and Messerli found evidence for underlying mappings between the conceptual domains of "reading" and "food" (Herrmann & Messerli, 2020a) and "reading" and "motion" (Herrmann & Messerli, 2020b) in a corpus of 1.3 million reviews (see Nuttall & Harrison, 2020, for a stylistic study on English).

The distinction between metaphor "conventionality vs. unconventionality" (Philip, 2016) or "deliberate vs. non-deliberate use" (Reijnierse et al., 2018) is currently one of the most promising research avenues, with high potential evident in vector-space models, ideally representative of particular discourse areas (such as German Modernism). So far, corpus-stylistic studies on the basis of the VUAMC fiction sample show a strong predominance of conventional, non-creative metaphors, often in the form of personification (Dorst, 2011). Related are questions about "metaphor aptness," cutting across genre, and reader response, which involves computational modeling of readers' judgement (Bizzoni, 2019). Combining ratings and computational stylistics, Jacobs and Kinder (2018) found structural differences between "literary" metaphors (created by renowned poets) and "nonliterary" ones (created by non-professional authors), including sonority score, length, and surprisal value.

CS research on metaphor depends heavily on efforts in NLP and corpus linguistics, on progress in automatic detection, and on vast dataset annotation. At the same time, dedicated research on metaphor in specifically *literary* genres is highly needed, with domain-specific corpora to be utilized for answering questions about frequency distribution, but also about the types and functions of metaphor, in particular, its vagueness/polysemy. The most promising initiatives are those focused on identifying conventionality/novelty as well as those integrating reader's ratings with CS analyses, advancing the field to a data-driven theory of how metaphor activates the minds of readers.

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7 https://www.mappingmetaphor.arts.gla.ac.uk/ The project *Mapping Metaphor* systematically identifies instances where words extend their meanings from one domain into another. It is, however, limited to the English language and its powerful visualization tool is not open to further – potentially literary – data.

Narratology and Dramaturgy

The computational study of narrative and dramatic structure is a fast-growing area of study (Mani, 2013), with a particular emphasis on characterization, character networks, narrative perspective, narrative time (Sachs & Piper, 2018; Underwood, 2018a), and plot structure (Jockers, 2017; Piper, 2018, pp. 42–65; Schmidt, 2015). Related work in computational linguistics and information studies has focused on "event detection" (Sims et al., 2019), an area increasingly seen as the building block of larger narratological concepts like "plot" and "point of view." Sims et al. (2019) have developed new methods for the detection of "real" versus hypothetical events in literary narrative, with respect to the events as they occur within the narrative, and have shown that irreality is strongly correlated with literary prestige.

Advances in natural language processing on entity recognition, dependency parsing, and co-reference resolution (Bamman et al., 2019a, for English; Rösiger et al., 2018 for German) have initiated a prolific study of literary characters. Using the resource BookNLP (Bamman et al., 2014), Piper (2018, pp. 118–146) finds that literary characters in novels are more linguistically homogeneous when compared to other kinds of nouns. Characters' uniqueness – rather than being a function of richer embodied description – may thus derive either from their speech or from readers' inferences. In the same work, Piper shows how women protagonists written by female novelists in the nineteenth century exhibit significantly higher levels of a semantics of "interiority" than other types of characters, providing supporting evidence for the role of women writers in forming literary archetypes. Cheng (2020) has observed changing semantic associations of different body parts with male and female characters, providing a more nuanced portrait of our understanding of literary character gendering. Also, based on recent advances in sentiment analysis, Jacobs's (2019) *SentiArt* tool allows computation of the emotional and personality profile of fictional characters such as Harry Potter or Voldemort and can be used to identify figures on the basis of generic character features, such as "extraversion" or "emotional stability". (For a broad survey of sentiment analysis in literature, see Kim & Klinger, 2018.)

While much of this work looks at characterization as a form of description, characters are also crucially shaped by the way they communicate and mentalize, which feeds into the subject of "narrative perspective." CS tackles questions about how speech, thought, and writing representation constructs fictional characters, molds the narrator-character relationship, and characterizes the narrator's stance (Leech & Short, 2007). Burrows (1987b) examined characters'

idiolects, the distinctive stylistic patterns of individual speakers within texts. Semino and Short (2004) were the first to operationalize and compare "perspective" across fictional and non-fictional genres, a framework applied by Busse (2010) and extended to German by Brunner (2013). Both Long and So (2016) and Brooke et al. (2017) have explored computational methods for studying "free indirect discourse."

Questions about character dialogue have received growing attention: studies on novels (Egbert & Mahlberg, 2020; Muzny et al., 2017) and plays (Vishnubhotla et al., 2019) suggest similarities between fictional dialogue and face-to-face communication, and between narrative passages and more informational and narrative prose. Among the many fertile avenues for further research raised by Muzny et al. (2017) is the suggestion that, viewed through the lens of higher-level abstract grammatical features, free indirect discourse is a narrative distillation of dialogue.

Research in CS has also examined the role of social networks in shaping literary discourse. Ardanuy and Sporleder (2015) suggest that genres have a "social network" signal that is as strong as "semantic" signals in predicting their genre classification. Other studies have assessed the similarity between fictional and real-world networks (Volker & Smeets, 2019), urban versus rural settings within novels (Elson et al., 2010), the evolution of dramatic genres in English over three centuries (Algee-Hewitt, 2017), and authorship in French classical theatre (Schöch, 2014). Trilcke (2013) explores network analysis for German plays, while Fischer and Skorinkin (2021) show the state of the art in Russian novels and plays. Tangherlini (2017) uses network models to analyze the narrative structure of "legends," from folklore to contemporary conspiracy theories. A great deal of work is required to better understand and define the nature of "relationships" and "interaction" in literary discourse as a means of constructing social networks.

Narrative Time and Space

Temporality is one of the defining features of narratives, as these are representations of event-sequences (Scheffel et al., 2013). Narrative theory holds that time is both a dimension of the narrated world and an analytical category for describing the way in which a story is narrated: typically, time is divided into "story time" (the temporal dimension of the narrated world), "discourse time" (the time of telling, i. e., the time it takes to narrate the fictional events, including formations such as order, duration, and frequency), and "narrating time"

(the temporality of the narrating act, describing the spatiotemporal position of the narrative voice).

Underwood's (2018a) modeling of story time in novels illustrates a dramatic decline in the duration of discourse time as a function of story time over the past three centuries. Sachs and Piper (2018) offer a theoretical framework for the multidimensional modeling of time, along with Meister (2005) and Meister and Schernus (2011). Ikeo (2019) studies the distribution of verb tense in contemporary fiction. Given that most text-based models currently in use treat literature as a static unit (whether as bags of words or vectors), much future research is needed to better understand the impact of differentiating story time from discourse time and narrating time.

Computational research into the relationship between literature and "space" has been robust and growing (Cooper et al., 2016; Gavin & Gidal, 2017; Tally, 2017). Its backbone resides in approachable geographic information systems (GIS) that integrate databases and visualizations, allowing for spatial models of the textual and contexual dimensions of literature. Pioneering projects on fictional landscapes of literary texts are Piatti's *Literary Atlas of Europe*[8] (Piatti, n. d.) and Cooper and Gregory's *Mapping the Lakes*[9] (Cooper & Gregory, 2011). Wilkens (2013) illustrates how researchers can integrate social demographic data with literary data, challenging longstanding theories about the geographic representations of US fiction related to the effects of the American Civil War. Work at the Stanford Literary Lab reported an increasing importance of "London" in English nineteenth-century novels, and an exploration of fictional cartographies correlated emotions with social power-relations within London's urban landscape (Stanford Literary Lab, 2016).

The computational modeling of the temporal and spatial dimensions of literature has a vast research potential, with future studies more fully nuancing questions about the interrelations of world building, narration, and extra-textual time and space.

Sound and Vision

Research in literary studies, linguistics, and book history has long emphasized the importance of visual and phonic dimensions of texts, as well as their performative and experiential correlates. In addition to words and letters, texts are

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8 http://www.literaturatlas.eu/en/index.html
9 https://www.lancaster.ac.uk/mappingthelakes/

comprised of graphical components (white space, typeface, illustration, etc.) as well as underlying phonological aspects encoded through the relationship of word components and their enunciation. New work in the field is beginning to address these extra-literal dimensions of literary discourse.

"Sound" in its broadest sense can be understood to comprise an array of linguistic aspects that are bound to diverse formal and semantic features (Jacobs, 2015b) and play a particular role in the phonological as well as on the prosodic levels of language. Examples include the phonological inventory related to core units such as phonemes and tonemes, phonology-based stylistic devices such as rhyme, meter (Haider, 2021), and other figures of phonological recurrence (Kraxenberger & Menninghaus, 2016, 2017), including acoustic, suprasegmental features above single speech sounds. Some of these features regularly interact (such as poetic rhythm and meter) or frequently co-occur and influence each other (such as end rhyme and meter).

All these different aspects comprise the particular "melodies" of literary texts, that is, its musical features. Consequently, these diverse aspects lead to different (re)presentations of sound (abstract-phonological; acoustic-prosodic) that have been investigated in relation to the different perception modes by which they are shaped (silent reading; reading aloud; listening to literary texts read aloud). Although tonal and rhythmic dimensions of discourse are not limited to poetry, they are hallmarks of a genre that invites a distinctive set of research questions (versification combined with syntactical and semantic openness, a high density of formal craftedness) which generally distinguishes it from prose (Bories et al., in preparation).

Notable new work in CS also addresses the auditory and performative nature of texts. A computational-stylistic approach is offered by Katsma (2014), while Clement and McLaughlin (2016) have introduced methods for assessing audience behavior in audio files of literary readings, such as applause. Macarthur et al. (2018) have produced new work that looks at twelve possible acoustic measures of spoken texts to test for the existence of "poet voice" (a familiar performative style common to poetry readings). With the growth of audio archives of literary texts (audiobooks and poetry readings), a wealth of new research is made possible to study relationships between the semantic and acoustic features of texts.

Book historians and media studies practitioners have long argued for the importance of the material nature of texts. This may include visual elements of texts such as bindings, illustrations, or covers, or it may include the physical formats in which literature is circulated, up to and including oral formats such as poetry readings or audio books. While still nascent, the field of *image analytics* is beginning to play a role in CS work. Houston and Neal's (2013) work

was the first to explore the meaning of white space in genre distinctions, while Fyfe and Ge (2018) have developed initial metrics for the study of newspaper illustrations. Piper et al. (2020) are using document image analysis (DIA) to study the evolution of scientific graphic practices that underpin truth claims since the eighteenth century, such as footnotes, tables, diagrams, and illustrations (Abuelwafa et al., 2018).

Such innovative approaches move past the primary understanding of the linguistic basis of texts to consider other material dimensions of reading and textual meaning. Incorporating auditory and visual aspects initiates important new avenues for studying the diverse medial forms of literature and its reception by readers.

Social Approaches

Inequality, Bias, and Identity

While the study of large numbers of texts and their historical and social representativeness already implies a social dimension, CS has begun developing more explicitly socially-oriented research frameworks. One of the key areas that examines the relationship between representation and social power is that of *inequality*. Deriving from the theoretical work of cultural studies and the Birmingham School (Hall, 2006), research in CS is now exploring inequalities and biases of representation within literary and other cultural documents. This work uses a two-pronged theory of "representation" drawn from the work of Spivak (1988), where researchers explore biases of representation at the level of agents (authors, characters, publishers, editors), as well as biases of representation at the level of form (style, semantics, topoi, etc; Brown & Mandell, 2018). For example, Underwood et al. (2018) have shown a massive decline of women authors of fiction in the twentieth century (the first form of representation) but also a decreasing differentiation of the qualities in the way male and female characters are portrayed, suggesting a growing equality of gender according to the second level of representation. Nevertheless, Kraicer and Piper (2019) have subsequently shown how male characters consistently outnumber female characters across a range of genres and readerships in contemporary fiction, suggesting that longstanding gender hierarchies are still in place. In addition, using random models, they also illustrate the strong heteronormativity of fictional social networks. Using library records from the well-known Muncie, Indiana

data set, Tatlock et al. (2018) have explored gendered reading practices to identify literary qualities that span readerships.

Not limited to the analysis of gender, researchers have also begun addressing questions of race with respect to literary and cultural production. So et al. (2019) have used text re-use algorithms to better understand the ways in which different racial communities deploy the practice of Biblical citation within literature (So et al., 2019; So & Roland, 2020). Algee-Hewitt et al. (2020) have used collocate analysis to study the proliferation of racial slurs in US fiction within a set of 18,000 American novels. Evans and Wilkens (2018) have shown how writers of different ethnic origins construct the imaginary space of Britishness differently, while Lee et al. (2018) have combined topic modeling and publishers' networks to rethink race in Shakespeare.

Alongside these more applied approaches, a burgeoning theoretical field of research aims to go beyond the limitations of binary modeling and imagine more nuanced ways of engaging with questions of race, gender, and sexuality (Koolen, 2018; Losh & Wernimont, 2019; Mandell, 2019; Noble, 2019; Risam, 2015, 2019). Future research will increasingly bring these two fields into dialogue with one another in order to construct more flexible modeling possibilities with respect to questions of identity, bias, and inequality.

Prestige and Literary Quality

Another line of research investigates the evaluation of literature by readers, professional critics, and institutions with an eye toward the differences among reading communities and literary institutions. Here the goal is not to infer "intrinsic" literary qualities or value-systems, but to assess the discursive priorities of different reading communities and to understand these as part of larger social fields of interaction. This line of research is shaped in large part by Bourdieu's (2000) theories on social distinction and cultural capital. If distinction is what defines a book's success and also social meaning, what are the observable textual and contextual factors of such distinction? Questions extend to larger issues of canonicity, and also of prestige, and thus to social, political, and economic power. Within this predominantly social perspective, some approaches have a stronger "formalist" orientation, concentrating more strongly on the textual correlates of "literary quality" (van Dalen-Oskam, 2014; van Peer, 2008).[10]

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10 Measures of textual quality have been developed for some decades in applied computational linguistics for discourse processing and educational software (McNamara et al., 2014;

Piper and Portelance (2016) identify strong stylistic differences between prize-winning and best-selling contemporary fiction, which revolve most distinctively around questions of "time," with nostalgic time-frames more prevalent in high-culture productions (see also English, 2016). Similar work by Jannidis et al. (2019) compared high- and low-brow literature in German, presenting evidence of a higher genre-internal variation in low-brow texts than previously assumed. Underwood (2019) examines the historical change of "literary prestige" from the mid-nineteenth to the mid-twentieth century by studying professional ("elite") literature periodicals, finding increasing semantic predictability for whether a novel or collection of poetry would be included in the reviews (and thus assigned "prestige"). He also finds an increase in stylistic stratification since the middle of the nineteenth century between prestigious and non-prestigious writing. Ashok et al. (2013) point to a positive correlation between sentence complexity and literary success. Similarly, van Cranenburgh et al., (2019) examine correlations between textual features of Dutch novels and reader ratings, finding that higher semantic complexity is matched by higher appreciation. For American English poetry, Kao and Jurafsky (2012) report as a key indicator of "high-quality" poetry the frequency of references to concrete objects. Extending this research, Jacobs (2018b) presents a comprehensive list of co-determinant features of literary quality, including vocabulary familiarity, sentence embeddings, coherence, and cohesion.

Using an annotation procedure and rule-based methods based on a taxonomy of literary values (Heydebrand & Winko, 2008), Messerli and Herrmann (in preparation) examine "literary quality" in online lay book reviews, finding a high proportion of effect-oriented "hedonistic" values, but also of formally oriented ones that concentrate on writing style and composition.

Social Reading

In the Digital Literary Sphere, Murray (2018) draws on the earlier book-historical work of Darnton (1982) to make the case for the importance of studying literature within a larger digital ecosystem, one important component of which is the space of reader responses that can be captured online. Going back to the work of Fish (1980), the guiding theoretical framework is that different communities of readers help co-construct the meaning of texts. Rebora et al. (2021) present the state-of the art in "digital social reading" (and writing) studies, addressing

Crossley et al., 2019). Recent predictive modeling tools for literary texts are *QNArt* and *SentiArt* (Jacobs, 2018a,b; 2019; cf. https://github.com/matinho13/SentiArt), which also work on other languages than English.

the interactions among at least ten dominant categories, including reading-oriented, institutional, and community-oriented research. Studies in this direction include an analysis of different rating behavior across different platforms like Goodreads and Amazon (Dimitrov et al., 2015); the relationship between the sentiment of reader comments and the texts they are responding to (Lauer, 2020); an examination of the different frames of attention of scholarly readers when compared to "general" readers, by exploring scholarly citations of books with reader "shelving" behavior on Goodreads (Bourrier & Thelwall, 2020); or the construction of literary canons between academic anthologies and Google's knowledge graph (van der Deijl et al., 2019). Riddell and van Dalen-Oskam (2018) explore the levels of distinction between reader self-reports and find much greater overlap than theories might otherwise predict. Another promising area of research in this vein uses text-reuse algorithms to understand how literary works are cited by either professional or lay readers (Piper & Manalad, 2020), as well as the social re-use of texts within nineteenth-century US periodicals (Cordell et al., 2015). Bode (2018) provides important new resources for the study of the social circulation of texts within Australian periodicals.

One of the major challenges of research into social reading practices is access to corporate data and the inaccessibility of algorithms used for the presentation and organization of data. Another challenge lies in the generalizability of online behavior due to demographic biases surrounding different platforms. Nevertheless, this avenue promises to move beyond the fictional "ideal" reader often employed in traditional literary studies to study actual reader behavior.

Alongside these text-analytical approaches, there is a vibrant tradition of empirical reader studies for the study of readers' affective evaluation of literary texts. Schindler et al. (2017) outline a new questionnaire-based approach for identifying aesthetically induced emotions and Menninghaus et al. (2019) provide an overview of the definition of aesthetic emotions (see Section 3 for more detail). Future work will want to attend to developing more fluid definitions of "quality" as well as integrating research into readers' emotional responses with large-scale text analysis. As indicated in our concluding section, this is one of the more promising avenues for future research in CS.

Cognitive Approaches

A growing body of work in CS is concerned with readers' relationships to texts from a cognitive perspective. Examples mentioned above are studies of appreciation and prestige, with professional readers' judgments in the form of re-

viewers or prize committees, but also with lay readers' cognitive and affective responses to texts. Studies examine readers' responses through the textual traces they leave "naturally" online (e. g., on platforms such as Goodreads or Amazon) or by solicitation in controlled laboratory studies. Here, "readers" and their "responses" are modeled at the levels of reader type (professional, amateur, differently abled), social metadata (library or professional classification systems), textual responses (testimonials and reviews), and cognitive/affective responses (ratings, eye-tracking, brain-imaging, etc.).

Cognitive literary studies (CLS) represent an important complementary dimension to computational stylistics. The object of cognitive literary studies is to provide a valid general description of those aspects of the stimulus (i. e., literature) and context (e. g., reader personality, reading situation, socio-historical environment) that systematically influence *literary experience* (e. g., Hoffstaedter, 1987). In the broadest sense, literary experience encompasses directly or indirectly measurable responses accompanying the reading act (Iser, 1978), including bodily (e. g., heart rate or skin conductance changes), neurocognitive (e. g., brain activity modulations), and behavioral reactions (e. g., verbal reports, ratings, or eye movements; Bortolussi & Dixon, 2003; Jacobs, 2015a). Extensive reviews by Burke (2011), Schrott and Jacobs (2011), and Jacobs (2015a) agree that, apart from such an adequate description, the scientific study of literature must aim at explaining, predicting, and controlling (i. e., systematically modifying) literary experience. Only then will it be possible to answer the question *what literature does* and *why we turn to literary reading*.

Following up on mostly theoretical work by classical and modern poetics (for a recent review, see Salgaro, 2018), CLS published in specialized journals (e. g., *Poetics*, *Poetics Today*, *SSOL, Language and Literature*, or *Style*) provide ample evidence of the enormous diversity in theoretical perspectives, questions, hypotheses/models and methods used to tackle this rich and complex research field (cf. Sopčák et al., 2018). Some recent papers try to put order into the apparent creative chaos by (a) proposing classification schemes organizing CLS according to whether they use direct or indirect measurements, online or offline methods, or text manipulation (cf. Table 1 in Dixon & Bortolussi, 2015; Jacobs, 2015b) and (b) proposing a comprehensive theoretical framework, called the Neurocognitive Poetics Model of literary reading (NCPM; Jacobs, 2015a) that allows researchers to generate testable predictions concerning all the above aspects of literary experience. Whether such efforts help to establish (minimal) methodological standards facilitating future CLS remains an open question.

The primary challenges facing CLS can be grouped into the following two categories. The first concerns the stimulus material. The object "literature" is a vast domain and anyone wishing to enter this field can get lost already at this

stage of inquiry. Of course, it is possible to choose any literary text, prose or poetry, ever published somewhere on this planet, guided either by personal interests or the goals of some ongoing research project. Jacobs (2018b) lists as a best practice blueprint (a) a relevant set of publicly available, ecologically valid, and generally accepted literary test materials (e. g., the 154 Shakespeare sonnets); (b) appropriate open-access databases/training corpora relating to these materials (e. g., the Gutenberg Literary English Corpus, e. g., Jacobs, 2018a); (c) advanced qualitative-quantitative narrative analysis (Q2NA) and machine learning tools[11] for feature extraction from these materials (e. g., Bamman et al., 2019b; Herrmann et al., 2015; Jacobs, 2018b; Jockers, 2017); and (d) open-access reader-response databases ideally providing at least some previously collected data on the material the student is interested in. As these fields mature, we anticipate important opportunities for collaborations that align large-scale text analysis with readers' cognitive and affective responses to better address questions of literary meaning.

Outlook

Although wide-ranging in the types of questions that can be asked, the larger field of computational stylistics is converging around a series of shared methods and concerns. There is great potential in cultural heritage data, replenishing digital archives through retrodigitization (across languages and cultures, see Herrmann et al., 2020). This type of data curation may eventually lead to large-scale, anthropologically informed comparative research on the evolution of fiction and story-telling across human history. On the other hand, born-digital literary discourse includes new types of mass data, such as lay reader reviews, real-time response data on e-readers, or fan-based fiction writing, all of which require data-driven and scholarly-informed theorization.

Overall, the field is converging around shared techniques of text analysis, data representation, machine learning, and visualization. As with other fields in the data sciences, these methods bring with them a number of challenges that will shape forthcoming research. These challenges can be grouped into four domains.

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11 See the publications describing "LitBank", an annotated dataset of 100 works of English-language fiction to support tasks in natural language processing and the computational humanities: https://github.com/dbamman/litbank; see also GutenTag, an NLP-driven tool for digital humanities research in the Project Gutenberg corpus: http://www.cs.toronto.edu/~jbrooke/gutentag/

Theory

A general reproach of CS from those outside the field has been that it lacks a comprehensive effort at literary or linguistic theorization (Bubenhofer & Dreesen, 2018). Its focus on "simple wordcounts" as its primary means of drawing inferences reduces the rich complexity of its source material. A host of new work has begun to focus on the relationship between theory and model construction (Acker & Clement, 2019; Bode, 2020; Flanders & Jannidis, 2016; Gavin, 2018; Kuhn, 2019; Meister, 2020; Piper, 2017; So, 2017), with particular emphasis on better understanding the conceptual and experiential frameworks that current computational methods approximate (Gavin, 2020; Gavin et al., 2019; Herrmann et al., submitted). Future work could focus on two important and related issues: the first is what is described in the following section as "construct validation," i. e. the capacity of a given model to fully represent a theoretical construct. More work can be done to specify the constructs that are represented in a model (and those that are not). Second, we see a robust stream of future work focusing more explicitly on "theory testing," i. e. assessing the validity of theoretically linked constructs to explain real-world phenomena ("textual behavior"). There is potential for a systematic interrogation of the many existing literary theories, as well as for developing new theoretical models that guide the formation of data structures. Overall, future work will strive to close the gap between the data-intense and theory-rich extremes of (computational) literary studies.

Data

Collection and representativeness. As researchers begin working with larger collections of data and move towards making generalizable inferences from these data sets, two fundamental problems emerge with respect to sources of data for computational stylistics. The first problem is *access*, especially efforts to construct, integrate, and re-open[12] databases of classical, medieval, early modern, and post-eighteenth-century texts (including trans- and cross-cultural resources). This will require overcoming the copyright restrictions that currently hamper the availability and shareability of data (Burnard et al., 2019). It also includes negotiating conditions – including licensing – under which copyrighted materials may be collected, enriched, and shared for research. Another impor-

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12 Existing databases often reflect theoretical frameworks inherited from particular schools of literary studies (or non-scholarly principles incarnated in collections such as Gutenberg.org).

tant issue is format, where future developments are likely to choose more flexible metadata formats, including semantic web technologies (RDF, RDFS, and OWL) that may be combined with XML technologies.[13]

The second more conceptual problem concerns *sampling* and *representativeness* (Bode, 2018, 2020; Piper, 2019; Underwood, 2018b). Nearly all research until now has worked with non-probabilistic samples (i.e. convenience samples), which imposes strong limitations on the generalizability of findings to out-of-sample data (Bode, 2018, 2020). This is largely because, as Herrmann and Lauer (2018) discuss, probabilistic sampling in CS is very challenging, if not impossible, due to the lack of encompassing records (e.g., a list of *all* nineteenth-century novels, or of *all* library loans across a temporal and language space; for an attempt at gauging a specific text population, see Herrmann et al., 2021). Nevertheless, using *multiple* samples collected according to different theoretically-informed criteria and potentially from different sources is one way to gain confidence about the representativeness of any single estimation. Many estimations are robust across numerous kinds of sampling techniques (Underwood et al., 2020). Similarly, data scientists have begun to show how analytical steps can be undertaken to overcome the limitations of convenience samples (Salganik, 2019). Yet, there remains a tremendous amount of work to better understand the representativeness of available data sets across different languages and periods.

Metadata and Annotation. Another major hurdle is the paucity and/or reliability of metadata and annotations. While there are considerably more digital texts at our disposal than in the past, analysis is substantially impeded by the lack of consistent and validated metadata (e.g., author names, publication dates, genre classifications) on a large scale. In addition, a rich understanding of textual data beyond practices of tokenization (i.e. reducing texts down to word frequencies) is still lacking.

Considerably more work is needed to improve the bibliographic classification of texts, for example, author metadata, such as nationality, gender, and race, as well as genre classification. Underwood's work at classifying fiction, poetry, and drama in the Hathi Trust for English is a prime example of this kind of important work (Underwood et al., 2014). Aiming at facilitating similar studies, the German National Library is expanding external access to their complete

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13 See for example the Swiss initiatives KNORA "Knowledge Organization, Representation and Annotation" and SALSAH "System for Annotation and Linkage of Sources in Arts and Humanities" https://www.knora.org/

metadata online[14] and allows on-site research on the full texts of their born-digital text collections (Jannidis et al., 2019). Generally, encompassing and sustainable access to metadata beyond libraries is needed. This could be accomplished, for example, through linked open data, using semantic web technology for flexible data representation and access (World Wide Web Consortium, n. d.).

To facilitate the enrichment of metadata about literary collections, more work needs to be done to standardize and validate the large-scale annotation of data. A number of automated systems, including bookNLP (Bamman et al., 2014), help annotate texts at the lexical and phrasal level for categories like part-of-speech, dependency relations, named entities, and supersense categories (like verb and subject type). Similar functions are performed by infrastructure such as CLARIN, DARIAH, and tools such as CWB[15] or TXM.[16] Future work will develop robust systems for annotating increasingly complex features, such as metaphor (Herrmann, in press), narrative levels and time frames (Gius et al., 2019), and models of causality and surprise, as well as standardize existing feature annotation across multiple languages. Research into the best practices of integrating human and machine annotation will be a necessary component for the field to move forward (Kuhn, 2019).

Methodological Validation

The validation and standardization of tools, instruments, and methodological procedures signifies another key area for future work. First, it addresses what has been called "tool criticism," understood as "the evaluation of the suitability of a given digital tool for a specific task" (Traub & van Ossenbruggen, 2015). This aspect is what social sciences and psychology have long referred to as "construct validity" (Salganik, 2019), i. e., the fit between a measurement and the theoretical construct it aims to represent. Despite the decades of discussion in those neighboring fields, until recently, computational stylistics has had a tendency to move from tools to concepts. However, new contributions within CS increasingly emphasize a "theory-first" approach that focuses on developing critical constructs for which appropriate tools and measures are then developed. The goal of tool criticism is thus to "better understand the impact of any

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14 https://www.dnb.de/DE/Professionell/Metadatendienste/metadatendienste_node.html#sprg186916
15 http://cwb.sourceforge.net/
16 http://textometrie.ens-lyon.fr/

bias of the tool on the specific task, not to improve the tools performance" (Traub & van Ossenbruggen, 2015).

Another important factor is the role of human judgment. Researcher "degrees of freedom" can strongly impact findings and conclusions drawn from research (Simmons et al., 2011). CS, as an emerging field, should develop procedures for codifying best practices for estimating the stability and validity of concepts and model(s) and the appropriateness of conclusions that are drawn from them. For example, in topic modeling, a widely practiced method, implementation varies greatly with a lack of reflection on the impact of parameters on model outcomes (see Herrmann et al., submitted). In data visualizations, similar variation can be seen in the protocols used to generate them, as well as the uses to which they are put (Bubenhofer et al., 2019). Future work should focus on creating standardized procedures for data handling and reporting so that other researchers can evaluate researcher choices.[17]

Disciplinary Integration

Finally, we want to emphasize the aim of further disciplinary integration within the larger world of CS. We see computational stylistics as an integral part of other data-scientific endeavors like digital sociology, computational linguistics, and information studies. Building and supporting collaborations across disciplines will facilitate the important transfer of expertise across these domains and help build consensus around best practices, as well as avoiding the needless repetition of old debates. On the other hand, we see a need for further integration between CS and empirical experimental sciences, such as social psychology and neuroscience. Texts do not exist in isolation but are socially activated through readers' engagement and the institutions that help circulate those texts. Future research will want to better understand the relationship between textual qualities, which CS has principally focused on, and reader responses. The integration of these fields represents an exciting opportunity to gain further insights into the *meaningfulness* of literary discourse.

Note: In addition to the references that follow, our research coalition maintains the following *Zotero* data base for computational stylistics: https://www.zotero.org/groups/2358990/research_coalition_computational_stylistics

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[17] This includes open-science principles such as the pre-registration of hypotheses and the open dissemination of all data and code associated with a given research project, as is practiced for example by the *Journal of Cultural Analytics*.

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