The rise of prosociality in fiction preceded democratic revolutions in Early Modern Europe

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The English and French Revolutions represent a turning point in history, marking the beginning of the modern rise of democracy. Recent advances in cultural evolution have put forward the idea that the early modern revolutions may be the product of a long-term psychological shift, from hierarchical and dominance-based interactions to democratic and trust-based relationships. In this study, we tested this hypothesis by analyzing theater plays during the early modern period in England and France. We found an increase in cooperation-related words over time relative to dominance-related words in both countries. Furthermore, we found that the accelerated rise of cooperation-related words preceded both the English Civil War (1642) and the French Revolution (1789). Finally, we found that rising per capita gross domestic product (GDPpc) generally led to an increase in cooperation-related words. These results highlight the likely role of long-term psychological and economic changes in explaining the rise of early modern democracies.

political revolution | trust | cooperation | GDP | text mining

The English and French revolutions mark the beginning of the modern rise of democracy (1, 2). The Petition of Right in 1628, the Bill of Rights 1689, and the Declaration of the Rights of Man and of the Citizen of 1789, symbolize a change in political culture, and a shift from authoritarian institutions toward more democratic ones.

Despite a long research tradition, no consensus has yet emerged regarding the long-term causes of democratization in England and France. Analyses of 20th century revolutions suggest that democratic transitions co-occur with changing cultural attitudes and with rising financial, social, and human capital (3). However, it is unclear whether these shifts are a cause or a consequence of democratization. On the one hand, the establishment and maintenance of democracy is more likely in societies with higher openness, political tolerance, and trust (4–7), supporting the hypothesis that resilient democratic institutions require certain preferences (8, 9). However, the establishment of democratic institutions might also generate new preferences and increase the sense of liberty, trust, and cooperation among citizens (10).

The interplay between economics and cultural change is also unclear. On the one hand, democracy is more common in wealthier and better educated countries (11–14), and rising living standards are thought to shift psychological orientations and preferences toward cooperation (4, 15, 16). In industrialized countries, higher socioeconomic status is linked to higher level of trust and lower level of authoritarianism (17, 18). However, democratic transitions might establish institutional and legal frameworks, which also increase social trust and accelerate economic development (10, 19, 20).

Furthermore, it is worth noting that the English and the French revolutionaries were in a unique situation because, unlike in the 19th and 20th century revolutions, they could not rely on examples of prior successful democratic revolutions to support their causes. Democracy seems to spread when it generates political and economic success (13, 21). However, at the time, people had no evidence that democracy could work in reality and, as the writings of Edmund Burke and Joseph de Maistre demonstrate, many were questioning the viability of democratic institutions. In the same vein, while a recent study has highlighted the central role of openness to diversity in modern democratic transitions (6), this factor might be less relevant in early modern periods, when societies were more homogeneous and less interconnected.

Finally, the interplay between revolution, state breakdown, and state reconstruction can obscure how long-term shifts in economic development and prosocial attitudes lead to democratizing processes. For instance, while many modern democratic transitions were relatively peacefully (e.g., Portugal and Spain), others required protracted revolutionary and counterrevolutionary periods during which the cultural attitudes and institutions tended to mirror the preferences of the winning coalition, composed of elites with popular support (22–24). Also, while trust and economic development are related to democratization, revolutions are often triggered by economic recessions and occur in periods in which there is a loss of trust in the political system (24).

All together, these reasons contribute to making the origins of the English and French revolutions difficult to understand. In this paper, we aim to shed light on this question by analyzing long-term trends in cooperation-related words in theater plays. Text analysis is a robust method to measure long-term cultural tends. For instance, it has been shown to detect increasing subjective wellbeing since 1730 until the present (25), decrease in the "linguistic positivity bias" since 1800 (26), a decrease in

Significance

We analyzed a large sample of English and French theatre plays and tracked the dynamics of words related to cooperation and dominance before and after early modern revolutions. We show that prior to both the English Civil War and French Revolution, there was a sharp rise in the frequency of words associated with prosociality, trustworthiness, and sympathy vs. words related to authoritarianism, strength and anger. Interestingly, in postrevolutionary reactionary periods, characters became stronger and less trustworthy. Finally, we also show that variations in GDP per capita partially account for these psychological changes. These findings reveal the interplay between economic environment, psychological preferences, and political events and shed lights on the rise and fall of support for democracy.

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general emotionality and in positive emotions in the 20th century (27, 28), and a decrease in words related to norms of cultural tightness vs. looseness since 1800 (29).

Here, we will focus on the dynamics of cooperation (vs. dominance) in Early Modern plays by measuring the trends of cooperative attitudes (prosociality vs. authoritarianism), cooperative emotions (sympathy vs. anger), and cooperative traits (trustworthiness vs. strength) in England (n = 932; range: 1550–1800 CE) and France (n = 1,060; range: 1550–1900 CE). Prosocial attitudes are a core measure of cooperation (30), and as reviewed above, trust is a central aspect of social capital leading to democratization. Similarly, sympathy is an emotion related to reciprocity, which is essential for collective action (31). With these measures, we can assess the degree to which art patrons prefer plays depicting prosocial, sympathetic, and trustworthy characters in different time periods.

Theater presents a range of advantages. In contrast to the novel, which really emerged in the middle on the 18th century, plays were abundant from the late 16th century onward. In fact, the peak of English production was the early 17th century, with Elizabethan theater. Also, in contrast to other genres such as the novel or the various genres of poetry, they are very uniform over the period because of the constraints of stage performance. This means that the frequency of words is less sensitive to changes in style.

We chose to calculate the relative prevalence of cooperation-related words in relation to dominance-related words, rather than the frequency of cooperation-related words alone. Overall word frequencies can vary for a number of reasons, related to particular genres (e.g., comedy, tragedy) or writing styles. For instance, if the number of function words in the text increases because authors build more elaborated sentences, this would decrease overall frequencies of any particular dimension. In addition, if plays have more emotional content in a particular period, this would increase the frequency of all emotions (both related to cooperation or to dominance). Comparing words belonging to similar semantic groups (emotions, traits, and attitudes) allows us to control for these variations.

After obtaining the raw counts (#) for each set of search terms, we computed three cooperation-to-dominance ratios for each text using the same general formula, but using different proxies (one for each semantic group: attitudes, emotions, and traits):

$$\textit{Cooperation} - \textit{Dominance ratio} = \frac{\#\textit{Cooperation words} - \#\textit{Dominance words}}{\#\textit{Cooperation words} + \#\textit{Dominance words}}$$

Following the same procedure as Jackson et al., (29), we composed our bags-of-words in three steps: 1) we chose word sets from modern psychometric tools; 2) generated synonyms and hyponyms of these words using modern dictionaries (WordNet); and 3) used word2vec to ensure that the final word sets were consistent with the Early Modern use of our proxy concepts of cooperation.

We chose prosociality, sympathy, and trustworthiness as proxies of cooperation, and authoritarianism, anger, and strength as proxies of dominance, obtaining the ratios "prosociality-to-authoritarianism" (attitudes), "sympathy-to-anger" (emotions) and "trustworthiness-to-strength" (traits). For the traits ratio, we directly extracted key words of questionnaires measuring prosociality (e.g., "care," "help," "assistance") (32) and authoritarianism (e.g., "authority," "obedience") (33). For the emotions ratio, a recent data-driven approach has shown that classical affective judgments of fairness and dominance where highly correlated with "empathic pain" and "anger," respectively (34). Thus, we measured the relative prevalence of words related to sympathy (e.g., "compassion," "kindness," "warmth") and to anger (e.g., "rage," "choler," "fury'). For the attitudes ratio, we chose trustworthiness (e.g., "sincerity," "loyalty," "fidelity") and strength (e.g., "force," "power," "authority"), as these have been shown to correspond to very stable categories in facial expressions (35–37), and trust-related cues have been shown to rise in European portraits over the period 1300–2000 (38). Our complete set of search words is depicted in *SI Appendix*, Table S1. Crucially, we assessed the internal and external validity of our bags-of-words using factor analyses, correlations with well-validated measures for modern texts (39), and by assessing whether our tool differentiated comedy and tragedy, as the latter genre is more likely to depict narratives of power and status (see *SI Appendix* for details).

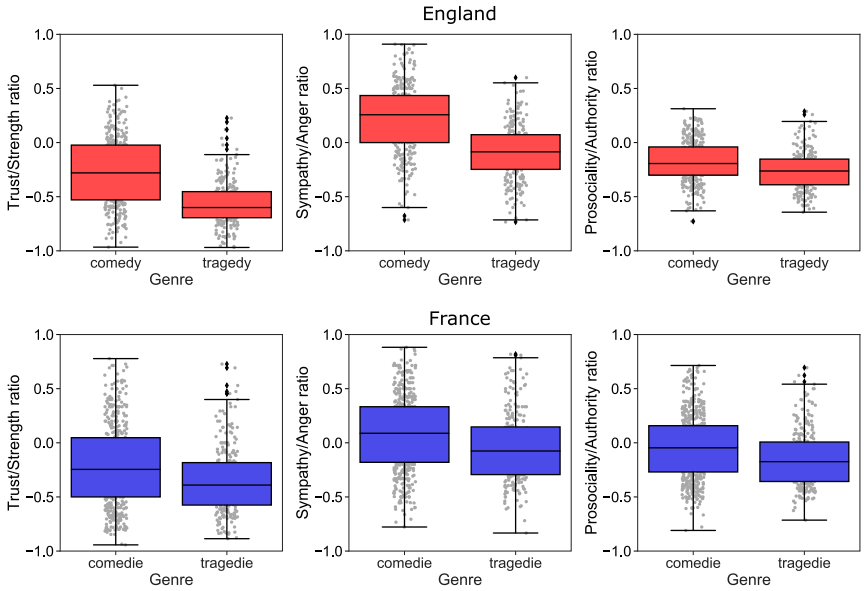

Fig. 1. Contrast between genres across all cooperation-to-dominance ratios. As expected by a priori knowledge of these genres, comedies rated higher in all three cooperation proxies (trustworthiness-to-strength [*Left*], sympathy-to-anger [*Center*], and prosociality-to-authority [*Right*]) than tragedies, for both England and France.

Our methodology provides two significant contributions: Most quantitative cultural research on democratization focuses on the last 100 y. However, the determinants of early modern democratic shifts (starting more than 350 y ago) remain empirically unexplored, and as we reviewed above, these can differ from those of modern processes. Second, by analyzing the preferences toward plays displaying prosocial, sympathetic, and trustworthy characters, we are measuring the shared and public interest for cooperation among the intellectual and economic elite. Since this group is thought to drive the ideological struggles after state breakdown (23, 24), we can specifically assess whether these preferences preceded or followed the revolutionary periods.

Based on the review above, we will test whether 1) cooperation-related preferences rise before democratic revolutions, or whether 2) democratic revolutions increase these preferences. In addition, we will explore the role of economic development in explaining the rise of the psychology of cooperation by assessing the correlation between gross domestic product per capita (GDPpc) and prosocial attitudes, emotions, and traits. Using cross-correlation and lag analyses, we will then test whether prosociality precedes or follows economic development (in *SI Appendix, Supplementary Materials*, we will report explorative analyses with other socio-economic variables).

Results

Most plays in our sample could be classified according to their genre, most commonly comedies and tragedies (*SI Appendix*, Fig. S3). Tragedies are known to be more likely to contain narratives of pride and power in comparison with comedies (40). We used this a priori knowledge to assess whether our tool was able to capture this difference between genres, thus providing a first measure of external validity (see *SI Appendix* for other measures of internal and external validity). All three cooperation-to-dominance ratios—trust-to-strength (trust), sympathy-to-anger (sympathy), and prosociality-to-authoritarianism (prosociality) were higher in comedies than in tragedies, both for England and for France (Fig. 1): trust for England: [$\beta = 0.93$, 95% CI (0.77, 1.08), t (896) = 11.7, $P < 0.001$]; trust for France: [$\beta = 0.36$, 95% CI (0.21, 0.51), t (923) = 4.8, $P < 0.001$]; sympathy for England: [$\beta = 0.89$, 95% CI (0.74, 1.05), t (900) = 11.2, $P < 0.001$]; sympathy for France: [$\beta = 0.35$, 95% CI (0.20, 0.50), t (924) = 4.57, $P < 0.001$]; prosociality for England: [$\beta = 0.46$, 95% CI (0.29, 0.62), t (911) = 5.4, $P < 0.001$]; prosociality for France: [$\beta = 0.32$, 95% CI (0.18, 0.47), t (1,033) = 4.4, $P < 0.001$]).

Fig. 2 shows raw data for the trust, sympathy, and prosociality ratios in plays. To assess the dynamics of these ratios across time, we computed two linear mixed models (LMMs) for each country, with year as a covariate and author as a random factor. We found that trust, sympathy, and prosociality increased over time in both England and France (trust for England: [$\beta = 0.35$, 95% CI (0.26, 0.41), t (169) = 8.36, $P < 0.001$]; trust for France: [$\beta = 0.33$, 95% CI (0.25, 0.41), t (317) = 7.80, $P < 0.001$]; sympathy for England: [$\beta = 0.32$, 95% CI (0.23, 0.40), t (159) = 7.39, $P < 0.001$]; sympathy for France: [$\beta = 0.23$, 95% CI (0.14, 0.31), t (270) = 5.07, $P < 0.001$]); prosociality for England: [$\beta = 0.28$, 95% CI (0.20, 0.36), t (159) = 6.68, $P < 0.001$]; prosociality for France: [$\beta = 0.31$, 95% CI (0.23, 0.38), t (284) = 8.10, $P < 0.001$]). (All slopes are standardized beta coefficients. All significance tests are two-tailed. Model details are depicted in *SI Appendix*.)

Cooperation terms (sympathy, trust, and prosociality) are more positively connoted than dominance terms (anger, strength, and authoritarianism). The observed rise of sympathy, trust, and prosociality could thus be related to a general increase in positive words. To control for this hypothesis, we computed the ratio of positive to negative words (positivity) using an English sentiment lexicon (41) available at https://www.cs.uic.edu/~liub/FBS/sentiment-analysis.html#datasets and a French sentiment lexicon (42) available at https://www.kaggle.com/rtatman/sentiment-lexicons-for-81-languages/download. We found that positivity decreased slightly over time in the English dataset [$\beta = -0.09$, 95% CI (−0.19, 0.01), t (227) = −1.77, $P = 0.08$] but increased in the French dataset [$\beta = 0.18$, 95% CI (0.09, 0.26), t (227) = 4.03, $P < 0.001$].

Since positivity increased with time in France, we repeated the models for trust and sympathy, adding the positive-to-negative ratio as a covariate (*SI Appendix*, Tables S5–S7). We found that in France both positivity and year contributed independently to the growth of trust [β-year = 0.28, 95% CI (0.21, 0.36), t (321) = 7.17,

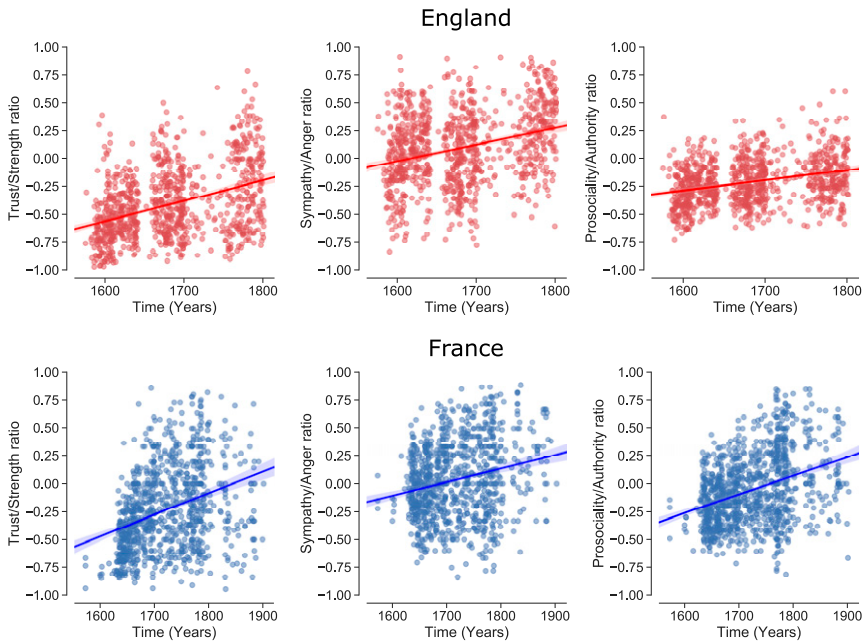

Fig. 2. Dynamics of trustworthiness-to-strength (*Left*), sympathy-to-anger (*Center*), and prosociality-to-authority (*Right*) ratios across time. The overall trends were consistent across different theater genres (*SI Appendix*, Fig. S3).

$P < 0.001$; β-positivity = 0.25, 95% CI (0.19, 0.31), t (924) = 8.14, $P < 0.001$] and sympathy [β-year = 0.16, 95% CI (0.09, 0.24), t (268) = 4.16, $P < 0.001$; β-positivity = 0.39, 95% CI (0.32, 0.45), t (919) = 12.21, $P < 0.001$], while for prosociality only year was a significant contributor [β-year = 0.30, 95% CI (0.23, 0.38), t (277) = 7.93, $P < 0.001$; β-positivity = 0.58, 95% CI (−0.03, 1.98), t (1,024) = 12.21, $P = 0.06$].

Fig. 3 shows the dynamics of trust, sympathy, and prosociality ratios across political periods in 16th–18th century England and France. For England, the most relevant political event in this period is the English Civil War (1642–1651) between Parliamentarians and Royalists, which was won by the proponents of a stronger role for parliament in governance. Following the Civil War there were two distinct periods: The Restoration (1660–1688), when there was a compromise between Royalists and Parliamentarians, and the period after the Glorious Revolution in 1688, which marked the definitive end of the Royalist movement. In line with our hypothesis, trust, sympathy, and prosociality rose during the period preceding the Civil War.

To assess the dynamics of trust and sympathy across these periods, we ran LMMs with year, period (pre-Civil War, Restoration, post-Glorious Revolution) and their interaction as predictors, and author as a random factor. Based on this model, we computed the means and growth rates (slope) of trust, sympathy, and prosociality for each time period (Fig. 3 and *SI Appendix*, Table S8 and S9). We found that the growth rate was highest before the Civil War for all ratios. Conversely, the growth rate was negative during the Restoration. Crucially, we found that in comparison with the Restoration, the growth rate was significantly higher in the periods before the Civil War [β = 2.0, 95% CI (0.59, 3.42), t (635) = 2.75, $P = 0.006$] and after the Glorious Revolution [β = 1.6, 95% CI (0.29, 2.98), t (665) = 2.36, $P = 0.018$]. For sympathy, the absolute level was higher before the Civil War than during the Restoration [β = 0.9, 95% CI (0.28, 1.45), t (295) = 2.89, $P = 0.004$], but we found no significant growth rate differences between periods (all $P > 0.1$; *SI Appendix*, Tables S9 and S10). For prosociality, neither mean nor growth rate differences were significant (all $P > 0.1$; *SI Appendix*, Tables S9 and S10).

In summary, these results indicate that the rapid rise of trust, sympathy, and prosociality predated a major democratizing revolution. Moreover, trust decreased steeply in the reactionary period of the Restoration and only recovered when the parliament's powers were strengthened again after the Glorious Revolution.

During the same period in France, the most relevant political event was the French Revolution (1789–1799), which marked the transition from an absolutist monarchy to a republic. As in England, the revolution was followed by a reactionary period which saw the institution of empires (1804–1814 and 1851–1870) and the restoration of the monarchy (1814–1848), and ended with the institution of the Third Republic in 1870. For simplicity, and comparability with England, we divide this timeline into four periods: 1) pre-Revolution (<1789), 2) Revolution (1789–1799), 3) Empires and Restorations (1804–1870), and 4) the Third Republic (>1870). Fig. 3 depicts the dynamics of trust and sympathy across these periods.

To assess the dynamics of trust, sympathy, and prosociality across these periods in France, we ran LMMs with year, period, and their interaction as predictors, and author as a random factor (*SI Appendix*, Table S12). Based on these models, we computed the slopes of trust and sympathy for each time period (*SI Appendix*, Table S11). As in England, we found that trust was growing before the Revolution and decreasing afterward. Moreover, in comparison with the period of Empires and Restoration, trust growth rate was faster before the Revolution [β = 1.5, 95% CI (0.40, 2.51), t (688) = 2.67, $P = 0.007$], but this was neither the case for sympathy [β = −0.05, 95% CI (−0.40, 2.51), t (620) = −0.09, $P = 0.9$] nor for prosociality [β = 0.73, 95% CI (−0.25, 1.71), t (747) = 1.46, $P = 0.15$]. In the French data, the French Revolution itself seems to be the period of highest growth rate across all ratios, and for prosociality this growth rate was significantly higher than for the Restoration period [β = 4.86, 95% CI (0.06, 9.67), t (934) = 1.98, $P = 0.05$] (in England this data are not available because theater was banned during the Civil War).

In conjunction to the English data, these results suggest that the trustworthiness-to-strength ratio rose before the political revolutions, and declined afterward. However, the rise of the sympathy-to-anger and prosociality-to-authoritarianism ratios seems to have started before the political revolutions but did not

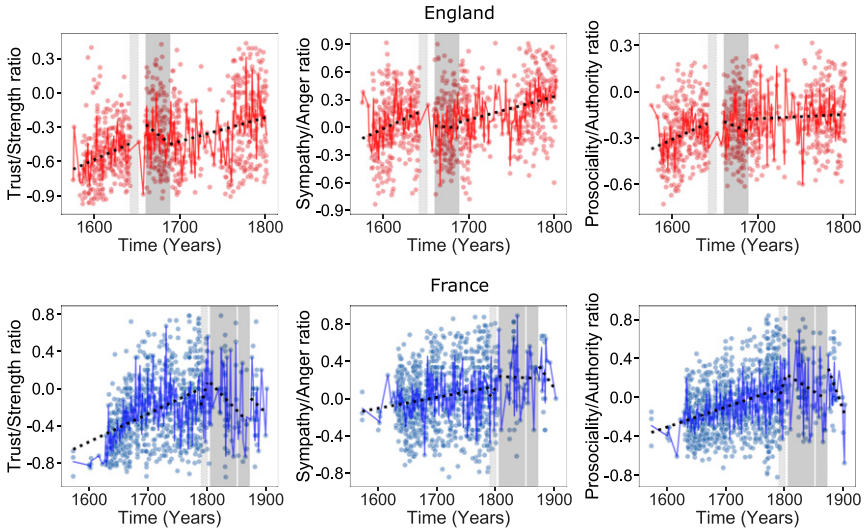

Fig. 3. Historical analysis. (*Upper*) England. Variation of cooperation-to-dominance ratios (red solid line) across three periods: Pre-English Civil War (<1643), Restoration (1660–1688, dark gray), Post-Glorious Revolution (>1688). English Civil War is depicted with light gray. Since theater was banned from the beginning of Civil War until the beginning of Restoration, we excluded this period from the analysis. (*Lower*) France. Variation of cooperation-to-dominance ratios (blue solid line) across four periods: pre-French Revolution, French Revolution (1789–1799, light gray), Empires and Restoration (1804-1870, dark gray), and Third Republic (>1870). Solid lines connect the means for each year. Dotted lines depict growth rate within each period.

significantly decline afterward. This unexpected result may suggest that political revolutions can produce a negative (although temporary) effect on social trust.

To explore the relationship between material affluence and the rise of trust and sympathy, we used estimates of GDPpc for England (43, 44) and France (45), the latter available only until 1800. Analyses with this and other socio-economic estimates for both England and France are shown in *SI Appendix*, Figs. S10 and S11.

English variations of GDPpc in the 16–18th centuries are depicted alongside trust and sympathy in Fig. 4. To investigate whether GDPpc was a good predictor of trust and sympathy, we ran LMMs with GDPpc as a covariate and author as a random factor. To assess model fitness, for each model we calculated the Bayesian information criterion (BIC). We found that GDPpc correlated with trust [$\beta = 0.27$, 95% CI (0.19, 0.35), t (243) = 6.80, $P < 0.001$, $BIC_{GDP} = 2473$], sympathy [$\beta = 0.31$, 95% CI (0.23, 0.39), t (225) = 7.48, $P < 0.001$, $BIC_{GDP} = 2494$], and prosociality [$\beta = 0.24$, 95% CI (0.16, 0.32), t (294) = 5.91, $P < 0.001$, $BIC_{GDP} = 2527$].

As we showed in the previous section, secular trends in trust/sympathy increased with time, as did GDPpc. To better evaluate the specific relationships between variations of GDPpc and trust/sympathy, we added time (year) as a covariate to the model (thus accounting for general time trends) (*SI Appendix*, Tables S14–S16). When controlling for time, the cyclical variations of GDPpc was still a reasonable positive predictor of sympathy [$\beta = 0.20$, 95% CI (−0.006, 0.41), t (865) = 1.91, $P = 0.056$, $BIC_{GDP+Time} = 2502$], but neither of trust [$\beta = -0.16$, 95% CI (−0.36, 0.04), t (856) = −1.51, $P = 0.13$, $BIC_{GDP+Time} = 2463$] nor prosociality [$\beta = -0.05$, 95% CI (−0.25, 0.16), t (889) = −0.47, $P = 0.64$, $BIC_{GDP+Time} = 2528$]. Crucially, adding time improved the model fit (BIC) of trust but neither of sympathy nor prosociality.

Importantly, trust decreases in the period after the English Civil War, which can affect the relationship between trust and GDPpc. To test this hypothesis, we added historical period to the model (*SI Appendix*, Tables S14). We found that trust was more strongly correlated with GDPpc before the English Civil War than during the Restoration [$\beta = 0.83$, 95% CI (0.23, 1.44), t (889) = 2.71, $P = 0.007$, $BIC_{GDP*Period+Time} = 2459$]. Again, adding period improved the model fit of trust but neither of sympathy (sympathy: $BIC_{GDP*Period+Time} = 2496$) nor of prosociality (trust: $BIC_{GDP*Period+Time} = 2538$).

Finally, we performed a time-lag analysis (or lagged regression) to assess whether GDPpc variations preceded or followed the dynamics in trust, sympathy, and prosociality. Time lag analysis are a common tool to assess the causality between two time series X and Y, by determining how well X at time T can be predicted by Y in different points in time, both before and after T (T − n and T + n, respectively) (46). For this analysis, we built models of trust, sympathy, and prosociality at time T predicted by year and 41 additional terms corresponding to GDPpc with different time lags spanning the interval [T − 20, T + 20], i.e., ranging from 20 y before to 20 y after the corresponding time point of trust/sympathy/prosociality. First, we computed the full model containing all 41 GDPpc time lags. Then, we performed model comparison using BIC and removed GDP lags step-wise until the best model was obtained. The only constraint was that the final model must include time (year) to control for global trends. Crucially, to prevent overestimation of GDPpc effects due to temporal autocorrelation, we computed the model using generalized least squares (GLS) (47) with time (year) as first-order autocorrelation term.

The best model for sympathy at time T (BIC = 471.6) included positive predictions of GDPpc at times T − 10 [$\beta = 0.50$, 95% CI (0.13, 0.87), t (179) = 2.63, $P = 0.01$] and T − 16 [$\beta = 0.63$, 95% CI (0.23, 1.03), t (179) = 3.07, $P = 0.02$]. In other words, when controlling for temporal global trends and autocorrelations, the sympathy-to-anger ratio was positively predicted by the levels of GDPpc 10 and 16 y earlier (*SI Appendix*, Table S20) but not by positive predictors after. In the case of prosociality, the best model (BIC = 441.3) included positive predictions of GDPpc at time T − 3 [$\beta = 0.57$, 95% CI (0.01, 0.10), t (175) = 2.71, $P = 0.007$] (*SI Appendix*, Table S21). In the case of trust, there were no positive GDP predictors in the final model, before or after (*SI Appendix*, Table S22).

We performed the same analyses for France. When controlling for time, GDPpc was a poor predictor of trust [$\beta = 0.03$, 95% CI (−0.04, 0.09), t (817.4) = 0.8, $P = 0.4$], sympathy [$\beta = -0.03$, 95% CI (−0.11, 0.04), t (819.7) = −0.9, $P = 0.4$], and prosociality [$\beta = 0.05$, 95% CI (−0.01, 0.12), t (828.7) = 1.6, $P = 0.1$] at time T (*SI Appendix*, Tables S17–S19). However, both ccf and time-lag analyses show that GDPpc variations strongly preceded both trust and sympathy (Fig. 5): The best model for trust at time T (BIC = 379.9) included positive predictors at times T − 2 [$\beta = 0.42$, 95% CI (0.25, 0.60), t (148) = 4.74, $P < 0.001$] and T − 19 [$\beta = 0.87$, 95% CI (0.32, 1.42), t (148) = 3.09, $P = 0.02$] while the best model for sympathy (BIC = 437.2) included a positive prediction of GDPpc at time T − 4 [$\beta = 0.81$, 95% CI (0.26, 1.36), t (148) = 2.90, $P = 0.004$] (*SI Appendix*, Tables S23 and

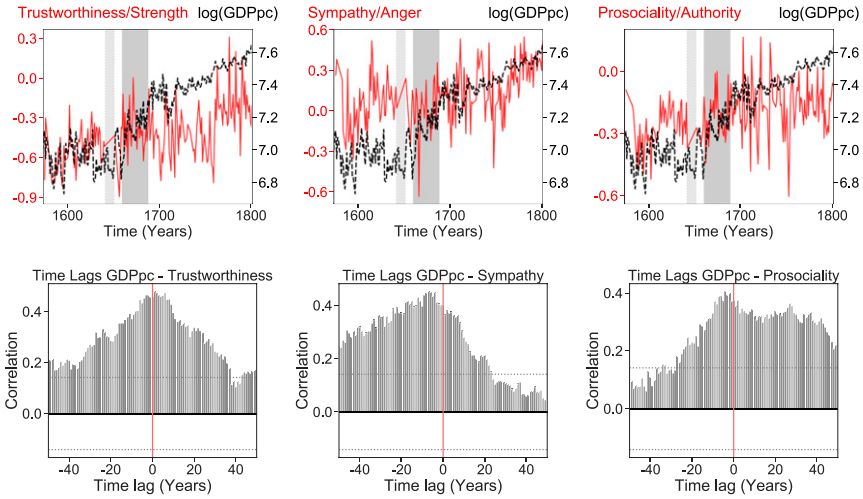

Fig. 4. Cooperation and affluence in England. (*Upper*) Variation of cooperation-to-dominance ratios (red solid line) and GDPpc (black dashed line) across three periods: Pre-English Civil War (<1643), Restoration (1660-1688, dark gray), Post-Glorious Revolution (>1688). Light gray area corresponds to the English Civil War. Lines plots depict the average of each year. (*Lower*) Time lag analysis assessing the causality between GDPpc and both ratios using ccf() function (*Methods*).

S24). For prosociality, the best model composed of GDP lags included only a positive prediction of GDPpc at time T − 15 [β = 0.51, 95% CI (0.20, 0.82), t (153) = 2.90, P = 0.0015]. However, this model did not survive the introduction of time as a covariate (*SI Appendix*, Table S25). All model details, databases, and scripts are available in *SI Appendix*, *Supplementary Materials* and in https://osf.io/emxqw/.

Overall, four in six measures suggest that GDP precedes cooperation-related psychological constructs, while in the remaining two GDP did not explain additional variance in relation to the general trend of increased cooperation with time.

Discussion

In this paper, we harnessed the content of early modern plays and extracted the relative frequency of words related to cooperation and dominance, operationalized as sympathy-to-anger, trustworthiness-to-strength, and prosociality-to-authoritarianism ratios. Under the assumption that the content of these texts reflects the preferences of authors and audiences, we evaluated the trends of cooperation-related preferences across time, how they related to democratizing revolutions, and how these trends covaried with economic development. Our central aim was to test 1) whether cooperation-related preferences preceded or followed early modern democratic revolutions, and 2) whether the rise of these preferences preceded or followed economic development.

First, we found that all proxies of the relative prominence of cooperation vs. dominance increased with time, and that this rise is not explained by a general increase in positivity. Second, we found that in England all proxies grew the fastest before the English Civil War and in France before the French Revolution. Interestingly, our data also shows that some factors negatively impact the overall preferences for cooperation. In line with previous research showing declining levels of trust after civil wars (48–50), our method shows a decreasing preference for trustworthiness in postrevolutionary periods. Finally, we tested the effects of GDPpc on all cooperation-to-dominance ratios and found that in four of six measures the variations in GDPpc (when accounting for global time trends) generally preceded isomorphic variations in trust, sympathy, and prosociality. Crucially, the latter findings survive rigorous controls for time series autocorrelation and are thus quite robust. There were two exceptions to this pattern: In the first, the relationship between GDPpc and trust in England was strong in the prerevolutionary period but not after, perhaps due to the negative effects of civil war in trust. In the second, GDPpc preceded the variations of prosociality in France, but this effect did not survive the introduction of time as a covariate. While interesting, these analyses rely on historical GDPpc estimates, which may be imprecise and should be revisited if better estimates become available.

Overall, our results support the hypothesis of a global historical trend toward increasing prosociality (51, 52) and support the view that democratizing revolutions may be the product of a broader shift away from authoritarian preferences and toward more democratic preferences (8, 9). Furthermore, our results are consistent with the hypothesis that rising living standards might contribute to the shift of psychological orientations toward cooperation (4, 15, 16). Note that such shifts may not only have caused political revolutions, but may also be responsible for less spectacular and more gradual institutional changes during the 17th and 18th centuries, such as increasing popular control over the monarchy, the abandonment of censorship and extrajudicial procedures, and the end of slavery. A famous symbol of these hidden institutional changes is the change in the importance of the Bastille. While the Bastille was long used as a prison for political dissidents and writers who had violated censorship laws (such as Voltaire), prisoner numbers decreased considerably over the 18th century, and on the 14th of July 1789, when it was stormed by the revolutionaries, only seven prisoners were found and released. In fact, even before the political revolutions, the silent rise of prosocial emotions may have already started to transform the European political systems.

Methods

Text Analysis. As a general approach, we acquired English (1550–1800 CE) and French (1550–1900 CE) theatrical texts from online repositories, preprocessed them using the Python Natural Language Toolkit, and for each text calculated three cooperation-to-dominance proxy ratios: trustworthiness-to-strength, sympathy-to-anger, and prosociality-to-authoritarianism. We then modeled how variation in these ratios was explained by the effects of time, political change, and GDP per capita, including a cross-correlation between these ratios and GDP per capita to assess the causal relationship between affluence and cooperative attitudes (see *Analysis* section below). Samples and methods were made public in Open Science Framework prior to the analysis (https://osf.io/emxqw/).

Source Materials. To test our hypotheses, we analyzed the texts of plays written during the Renaissance, between 1550 and 1800 CE. These plays were collected from a number of different repositories.

For English theater, our sample of 932 plays was divided into two main periods: 1) the early modern period, spanning the years 1550–1660 and 2) the

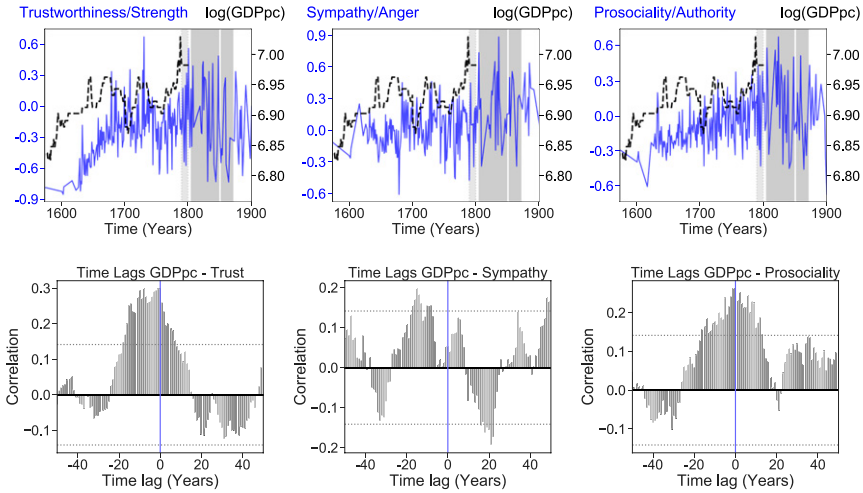

Fig. 5. Cooperation and affluence in France. (*Upper*) Variation of cooperation-to-dominance ratios (blue solid line) across four periods: pre-French Revolution, French Revolution (1789–1799, light gray), Empires and Restoration (1804–1870, dark gray), and Third Republic (>1870). Lines plots depict the average of each year. (*Lower*) Time lag analysis assessing the causality between GDPpc and both ratios using ccf() function (*Methods*).

Restoration/18th century period, spanning the years 1660–1800. For the early modern period, we collected 324 XML sources from the database at https://emed.folger.edu/corpus-search. These plays were already lemmatized and translated into modern English. In addition, 38 Shakespeare plays were collected from an associated source (https://shakespeare.folger.edu/download/). For the second period, due to the lack of availability of systematic theater repositories, we mined general databases for the Restoration (https://quod.lib.umich.edu/e/eebogroup/) and for the 18th century (https://quod.lib.umich.edu/e/ecco/).

We used custom python scripts (written in Jupyter Notebook) to download all of the documents containing at least one of the keywords in the list ["tragedy," "tragic," "comedy," "pastoral," "drama," "theatre," "theatrical," "tragic," "play," "farse," "farce," "comic"] in the title or subtitle. In addition, we excluded documents containing the words "opera" and "musical" in the title. From the list of downloaded files, we performed a visual inspection and excluded further documents not containing theater plays. The final sample for this period was 570 texts. Python scripts and the all text sources are available at https://osf.io/emxqw/(texts_and_mining_scripts.zip).

For French theater, we collected 1060 text files from the repository www.theatre-classique.fr/pages/programmes/PageEdition.php, plays written between 1550 and 1900, and with a genre tag containing the keywords ["comédie," "tragédie," "farce," "pastorale," "drame," "parodie," "proverbe"] and excluding ["ballet," "musique," "liturgique"]. We also excluded translations of Greek tragedies. Python scripts and all text sources are available at https://osf.io/emxqw/(texts_and_mining_scripts.zip).

Text Preprocessing. The first preprocessing step was the removal of theater-specific text, such as the prologue, epilogue, and nonspoken text, such as character names and stage directions. This was done using XML and TXT parsing tools (e.g., BeautifulSoup; ref. 53 and ElementTree; ref. 54) and custom Python functions. Scripts for theater text preprocessing and output files are available at https://osf.io/emxqw/ (preprocessing1.zip).

The second step was a standard lowercasing of the text, removal of nonliteral characters, expansion of contractions, including archaic contractions (e.g., e'en → even), and finally word lemmatization using WordNetLemmatizer (55). Scripts and output files are available at https://osf.io/emxqw/ (preprocessing2.zip).

Building the Sets of Search Terms. In order to generate the set of words associated with trustworthiness, strength, sympathy, anger, prosociality, and authoritarianism, we first searched appropriate "seed words"—which included synonyms and hyponyms—using the online tool WordNet 3.1 (55).

However, since this tool uses semantic trees built for modern English and French language use, some words either do not exist in our Renaissance corpus or are not used with the same meaning. To avoid a modern use bias, we checked whether the meaning of the "seed words" in the corpus is similar to their modern meaning by using the word2vec algorithm (56). This algorithm automatically associates a word to a vector (a set of coordinates) in a high-dimensional space, which describes the context in which each word is used. Crucially, this tool allows the extraction of terms similar to our seed words in this high-dimensional space, thus providing evidence about whether a seed word was used with the intended meaning. For instance, using this two-step procedure, we selected the following sets of seed words: trustworthiness: sincerity and confidence; strength: strength and power; Empathy: sympathy, compassion and pity; anger: anger, fury, rage, indignation and choler.

After obtaining these sets, we further expanded each set using the same word2vec algorithm, and retrieved the 10 terms most similar to each seed word in our corpus. For instance, the seed word pity was associated with the set ["pitty," "compassion," "mercy," "distress," "charity," "suffering," "weakness," "reproach," "kindness," "goodness"]. This ensured that a bottom-up approach was used in deriving the final sets of search terms, which reflected not only the modern word semantic trees (WordNet) but also how these concepts were used in dialogue of the plays (Word2Vec).

Finally, we eliminated words with opposite meanings to the seed word (e.g., "reproach" in the pity set), or words with potential confounding effects (e.g., "fever" in choler and "passion" in rage).

For French words, we followed the same procedure, but used the French version of WordNet 3 to derive modern terms (57) and word2vec to confirm the final word meanings. The explicit selection process for each language (word_selection_english.doc and word_selection_french.doc), and the final selection process, which harmonized the criterion (and meaning space) for the two languages (Final word selection_language_comparison.doc) are available at https://osf.io/emxqw/. The final search term lists for English and French, for both modern and early modern periods, are given in *SI Appendix*, Table S1.

In our analysis, we included only plays with word count > 1 for each proxy. This step was performed to filter out plays in which these words did not occur or used with other spellings. After this filtering step, the final play samples were 912 (trustworthiness-to-strength ratio), 908 (sympathy-to-anger ratio), and 919 (prosociality-to-authoritarianism ratio) for England and 935 (trustworthiness-to-strength ratio), 934 (sympathy-to-anger ratio), and 1,043 (prosociality-to-authoritarianism ratio) for France.

Analysis. To test how cooperation-related virtues and emotions varied with time and throughout historical periods, and to test the hypothesis that they increase with affluence, we ran LMMs with sympathy-to-anger, trustworthiness-to-strength, and prosociality-to-authoritarianism ratios as dependent variables, play author as a random factor, and year, GDP per capita, and historical period as predictors.

LMMs used the function lmer() with package lme4 (58). The best lambda transformations were found using boxcox() with the MASS package (59). Residual normality distribution was tested using the Shapiro–Wilk test. Models are reported using an ANOVA (type = II) and the R package Anova() for *P* values. Type III models are depicted as *SI Appendix, Supplementary Materials*. We tested for pairwise differences with emmeans() (60). We tested for Cook's distances and removed data points with Cook's distance > 1. Unless otherwise specified, all model residuals were normally distributed.

Time lag analyses for each cooperation ratio were performed by first computing the full model with all 42 regressors (year and the 41 GDP lags from GDP_{T-20} to GDP_{T+20}) with generalized least squares (47). Crucially, we controlled for temporal autocorrelations with the function corCAR1. Then, model selection was performed with the function stepAIC from the MASS package. This function compares models using the BIC and eliminates GDP time lags stepwise until the best explanatory model is found (i.e., the model with the lowest BIC).

All R scripts and datasets are available in https://osf.io/emxqw/.

Data Availability. Data have been deposited in https://osf.io/EMXQW. All study data are included in the article and supporting information.

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