

The Impact of Applied Cognitive Learning Theory on Engagement with eLearning Courseware

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Abstract

Since the emergence of eLearning in the 1990s, the craft of designing and developing online courseware has evolved alongside theoretical advances in the field. A variety of media combinations have been applied to course pages by eLearning practitioners, making it possible to examine learning concepts emerging from the research in the light of responses from learners. This study explores learner perceptions of engagement following completion of 393 courses developed by a commercial eLearning provider. Three media combinations are examined. Each course selected for the sample applies one of the three combinations on the majority of content pages. Responses from the 22,959 learners who completed post-training surveys are evaluated, with the goal of determining how learner engagement is influenced by the application of two cognitive learning principles — the multiple representation principle and the split-attention principle. Both principles are found to have limited impact on narrow audiences of intrinsically motivated learners, but significant impact on engagement with broader audiences of learners who are assigned or required to take the training. When applied in the field, these two cognitive learning principles dramatically broaden the audience of learners who feel engaged with the learning experience.

Keywords

eLearning, cognitivism, cognitive load, multimedia, engagement, Sweller, Mayer, instructional design

Introduction

In the decade and a half since the first HTML-based eLearning courses appeared on the Internet, online courseware has evolved through a series of stages. In some cases, the progression has gone from courses that show text and images on the page, with no audio, to partial use of audio, and later to full audio narration of text content. Experimentation with the mixing and matching of design elements makes it possible, now, to evaluate pedagogical principles on the basis of learner reactions to the designs. This study examines learner responses following completion of 393 courses developed by a commercial eLearning provider.

Three media combinations are examined, each of which applies a defined mixture of audio, on-screen text, and imagery. Each course selected for the sample applies one of the three combinations on the majority of course content pages. Responses from the 22,959 learners who completed post-training surveys are used to gauge learner perceptions of engagement with the material, with the goal of determining how learner engagement is influenced by the application of two cognitive learning principles — John Sweller's split-attention principle and Richard Mayer's multiple representation principle.

Working memory and cognitive learning theories

Substantial advances in cognitive modelling of the learning process have been made over the last two decades, with sizeable research programs supporting two related theoretical constructs — Multimedia Learning Theory and Cognitive Load Theory. Both theories rest on a foundation of research on the structure of working memory conducted in the 1970s and 1980s. Allan Paivio proposed a dual-coding hypothesis that suggested there are separate subsystems in the brain for representing verbal and visual information (Clark & Paivio, 1991; Paivio, 1986). The model subsequently built by Alan Baddeley became broadly influential as the dual-coding hypothesis gained empirical support (Baddeley, 1986; Penney, 1989).

In Baddeley's (1986) model, short-term memory consists of two buffers that are partially independent of one another. The visuospatial sketchpad is used to temporarily store visual information, and the phonological loop is used for auditory information (Baddeley, 1986). Because these memory stores are separate, there is a greater total capacity when both are used than there is when a single working memory store is used. This prompted Mayer and other cognitive theorists to propose the multiple representation principle — that learning can be facilitated through simultaneous use of audio and visuals. Multiple mediums are better than one for efficient storage and processing of information during the learning process (Mayer & Anderson, 1992; Mayer & Moreno, 1998b).

Seminal research by Baddeley, Penney, and others further explores the basic attributes of the visuospatial sketchpad and phonological loop, with significant implications for learning. The phonological loop takes in information automatically and stores it as an acoustic code (A-code) in the auditory buffer. There is no need for the individual to attend to the task. If the information is linguistic in nature, the auditory buffer automatically generates a phonetic code (P-code). Without attending to the task, humans translate acoustic signals into language sounds they can process as they learn (Baddeley, 1986; Penney, 1989).

The audio buffer has another important feature contributing to the learning process — a rehearsal component. The phonological loop repeats audio signals as they are held in the short-term buffer, which allows the signal to persist over time. A signal may loop for as long as sixty seconds, in the absence of other audio signals (Engle & Roberts, 1982).

The visuospatial sketchpad has substantially different capacities. It efficiently stores information on the shape, colour, location, and movement of objects, but it performs less well with the processing of language (Baddeley, 2000). Text on the screen does not flow into the visual memory buffer automatically. Conscious effort is required on the part of the learner to read. It also lacks the qualities of automatic rehearsal and persistence that were found in the audio buffer. Text flowing into the visuospatial sketchpad has to be processed into the phonetic code, and the resulting language sounds must be rehearsed by the learner in order to retain them in short-term memory (Penney, 1989).

These findings prompted Mayer, Sweller, and other cognitive theorists to recommend use of imagery to convey non-linguistic visual information and simultaneous use of audio for linguistic information. The split-attention effect identified by Chandler, Sweller, Mayer, Moreno, and others suggests that a single modality should not be used to simultaneously convey multiple streams of information (Chandler & Sweller, 1992; Mayer & Moreno, 1998a). Display of visuals and on-screen text at the same time "can overload the visual information processing system," but using the audio system for verbal information and the visual system for imagery is a more efficient division of labour (Mayer & Moreno, 1998b, p. 4). In short, words go better through the ears and images go better through the eyes.

Applying cognitive principles to elearning

When applied to the design of courseware, these two principles suggest that certain combinations of media facilitate learning more effectively than others. If you take the two principles together, they suggest that showing text and imagery concurrently on a course page, with no audio, is less effective than channeling most linguistic information through audio while concurrently showing non-text imagery.

To evaluate this design perspective, it might help to express it in simple equation form, like this:

Equation #1: Full Text + Image < Full Audio + Partial Text + Image

Thus, the more effective combination relies primarily on audio for linguistic information. Partial text is included on the right side of the equation because full audio courses often display occasional text on some pages (for example, a page label when a new topic is being introduced, or the name of a key term the learner may need to know how to spell). The right side of the equation reflects a dramatic shift of language to the auditory medium, though not a complete elimination of on-screen text.

When examining comparative data, it may be easier to express the media elements in abbreviated form. Henceforth, the following abbreviations will be applied:

FT = Full Text

PT = Partial Text

A = Full Audio

I = Image

Using this terminology, the equation described above is expressed as follows:

Equation #1: FT + I < A + PT + I

One of the two cognitive principles under discussion here — the split-attention principle — can be evaluated individually through an additional comparison of two page designs. The first design is one that shows all linguistic content as text on the page, and, at the same time, provides full audio narration of the on-screen text. Associated imagery appears concurrently on the screen. In this design, text is being doubled, with the same words flowing through two modalities.

It is possible to compare this doubled-modalities design to one that provides full audio narration and associated imagery, but limits the use of text on the screen. All linguistic content is presented through audio; images are displayed concurrently; but text is limited to the display of page titles, bullet points, names of concepts, and other short strings used to emphasise key points.

In simpler terms, you are comparing these two combinations:

A + FT + I

A + PT + I

The split-attention principle suggests that the second combination will facilitate learning more readily than the first. Expressed as an equation, this would be:

Equation #2: $A + FT + I < A + PT + I$

This suggests that taking something away from a multimedia presentation can boost learning. Less is sometimes more, a finding confirmed by Mayer *et al.* (Mayer, Bove, Bryman, Mars, & Tapango, 1996).

At the most general level, the first equation suggests that non-audio courses are not as pedagogically effective, consistent with both the multiple representation and split-attention principles. The second equation compares two designs that include audio to support further evaluation of the split-attention principle.

Henceforth, the first equation above will be referred to as Comparison #1 and the second as Comparison #2. Note that these two comparisons involve three combinations of media, since the right portion of both comparisons references the same media combination (A + PT + I).

Course and survey samples

Implications of the two comparisons described above will be explored through an examination of surveys filled out by learners following completion of eLearning courses developed by a commercial eLearning provider. Over the last decade, courseware developed by the provider proceeded through several evolutionary stages. Earlier stages involved production of courses on the left side of the equations (e.g., Text + Imagery, with no audio), while later stages applied page designs on the right side of the equations (e.g., Full Audio + Partial Text + Image). Comparisons can thus be made between learner reactions to courseware that applies fewer cognitive learning principles and courseware that more fully applies cognitive principles.

The sample includes more than 50 courses of each of the types described in the above equations. The breakdown of courses of each type and the associated number of learner surveys are indicated in Table 1.

Table 1
Selected courses and associated surveys for each media combination

Media Combinations	Number of Courses	Learner Surveys
FT + I	262	4,305
A + PT + I	71	14,893
A + FT + I	60	3,761

Topics covered by courses in the sample fall into three broad categories: business skills, technical skills, and regulatory compliance. Examples of courses included in each category are as follows:

Business skills: Communication, coaching, project management, time management, negotiating skills, and customer service.

Technical skills: Computer programming, systems administration, database management, and web development.

Regulatory compliance: OSHA, sexual harassment, food safety, alcohol safety, Title 31, and Sarbanes-Oxley.

Post-training surveys included both quantitative and qualitative feedback. The quantitative portion consisted of five statements the learner can agree or disagree with on a 7-point Likert scale. The five statements in this portion of the survey are as follows:

1. *This course overall was a good training experience for me.*
2. *This course's content met my needs.*
3. *This course is applicable to my job or career development.*
4. *I will be able to use these skills right away at my job.*
5. *I would like to take another course.*

The first statement addresses learner reaction at the broadest level. The second, third, and fourth statements focus on whether the training experience will be useful to the learner and whether the learner feels he will be able to apply the skills right away. The fifth statement reflects a broad assessment of the appeal of the learning experience, though it also may reflect time constraints the learner feels in his workplace, whether the learner wishes to be assigned further training, or other factors related to the learner's ability to complete training in the future.

Taken together, these statements — especially the first four — tend to reflect the learner's sense of engagement with the learning experience in the immediate aftermath of training. If the learner feels it was a good training experience, that the content met his needs, that it was applicable to his career and imparted skills that are immediately useful, then the learner has a reasonably strong sense of engagement with the learning experience. The question is whether advances in pedagogy — including the application of cognitive principles described by Mayer and Sweller — lead to increases in the various dimensions of learner engagement addressed by these five survey statements.

General results

For each of the three media combinations examined here, average scores for the five quantitative survey statements are provided in Table 2 below. Computed values are shown in Table 3 to draw the two comparisons under consideration.

Comparison #1 is shown in row 1 of Table 3, with the average values for Full Text + Image subtracted from the Full Audio + Partial Text + Image values. Comparison #2 is shown in row 2 of Table 3, with Full Audio + Full Text + Image values subtracted from Full Audio + Partial Text + Image values. Positive values in Table 3 would suggest increases in engagement with the application of cognitive pedagogy, while values near zero or negative values would suggest no boost or a loss of engagement.

Table 2
Average Engagement Scores

Media Combination	N	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
FT + I	4,305	5.42	5.39	5.41	5.24	5.52
A + PT + I	14,893	6.11	6.13	6.24	6.22	5.62
A + FT + I	3,761	5.56	5.56	5.68	5.58	5.31

Table 3
Comparisons #1 and #2

Comparison	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
#1 FT + I A + PT + I	.69	.73	.84	.98	.09
#2 A + FT + I A + PT + I	.54	.57	.56	.65	.31

Note to Table 3: All values are statistically significant at the 95% confidence level in two-tailed t-tests.

The first row of Table 3 shows substantial boosts in most of the measured dimensions of engagement for learners taking the Full Audio + Partial Text + Image courses as compared to the Full Text + Image courses. Learners' general feelings about the course were significantly boosted, and even greater increases were found for the three questions relating to usefulness and the learners' feelings that they will be able to put the new skills to use. Simultaneous application of the multiple representation and split-attention principles appears to correspond to significant improvements in learner engagement.

The second comparison allows us to evaluate the split-attention principle alone. Both media combinations in this comparison provide all linguistic content of the course through audio. Substantial boosts in the dimensions of engagement were found for the Partial Text group as compared to the Full Text group. Measures of the learner's general feelings and the first two usefulness measures were about half a point higher for the Partial Text group. The third usefulness measure — whether the learner feels he will be able to use the skills right away — is about two-thirds of a point higher for the Partial Text group. Whether the learner wants to take another course was increased more modestly in the Partial Text group.

Controlling for course type

It should be emphasised that these general findings do not account for differences in the composition of each set of courses. Subject-matter, audience, and other factors can influence the averages described above, especially if one audience or course type is represented in the sample for one media combination but not for another.

Table 4 breaks the averages down according to course type. As can be shown, the first media combination includes a course type not represented in either of the two other combinations — technical courses that are designed for an audience of programmers, systems administrators, and other information technology professionals. This audience may have different characteristics when compared to the audience of managers who often take business skills courses or the broad range of employees who take compliance courses.

Table 4
Engagement Scores by Course Type

Media Combination	Course Type	N	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
FT + I	Business Skills	3,288	5.47	5.44	5.39	5.31	5.47
FT + I	Technical	1,017	5.25	5.23	5.46	5.04	5.70
A + PT + I	Business Skills	3,586	5.65	5.64	5.80	5.75	5.69
A + PT + I	Compliance	11,307	6.25	6.29	6.38	6.38	5.59
A + FT + I	Business Skills	2,353	5.65	5.61	5.75	5.66	5.69
A + FT + I	Compliance	1,408	5.41	5.46	5.55	5.44	4.68

Table 5 draws the two comparisons of interest in this study, controlled by course type. The first row corresponds to Comparison #1, and it can only be drawn for business skills courses since there are no technical courses in the Full Audio + Partial Text + Image group. The second row corresponds to Comparison #2, where comparisons can be drawn for business skills and compliance courses.

Table 5
Comparisons #1 and #2 by Course Type

Comparison	Course Type	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
#1 FT + I A + PT + I	Business Skills	.18*	.19*	.41*	.44*	.22*
#2 A + FT + I A + PT + I	Business Skills	.00	.02	.05	.09*	.01
#2 A + FT + I A + PT + I	Compliance	.84*	.83*	.83*	.94*	.91*

Note to Table 5: Figures marked with an asterisk are statistically significant at the 95% confidence level in two-tailed t-tests.

For Comparison #1, increases are found on all measured dimensions of learner engagement, but the first four measures are substantially smaller than they were for the full sample. Limiting the sample to business skills courses produced boosts in engagement about a half-point lower than those found for the full sample on the first four measures of engagement. All five measures still reflect statistically significant increases with increases in job applicability and job use reaching four tenths of a point.

For Comparison #2, a dramatic difference is noted based on course type. Learners taking business skills courses had almost no increase in engagement based on application of the split-attention principle, while those taking compliance courses experienced dramatic increases in all five engagement measures.

Taken together, these two comparisons suggest that business skills learners experience modest increases in engagement with the addition of audio to the course design, but little additional benefit from the removal of on-screen text. Compliance learners, on the other hand, experience large increases in engagement from the removal of on-screen text called for by the split-attention principle.

Learner motivation and the impact of pedagogy on engagement

One interpretation of this pattern of results may bear further examination via the collected data. In many cases, the audience for compliance courses is broad. Sexual harassment training is often required for all workers in an office environment. OSHA training has similarly broad applicability, and food safety courses are usually completed by all food handlers in a restaurant or food processing environment. By comparison, business skills courses are often completed by management level employees, and, in some cases, these employees have influence over their professional development that allows them to select topics and courses. So, at any given time, a business skills learner may decide to develop her communication skills, negotiating skills, or perhaps her coaching skills. That level of developmental influence and self-direction is not often associated with the compliance training arena.

By this interpretation, cognitive pedagogy may have different impacts on a narrow audience of volunteer learners as compared to a broader audience of learners who are assigned or required to take the courseware. Learners who self-start may be more intrinsically motivated, and their internal motivation may make pedagogy less important than it is for the broader audience of externally motivated learners, resulting in a lower engagement boost for the self-starters with the application of new pedagogies. An analogy could be drawn to a teacher in a classroom. Regardless of the techniques the teacher uses, the most motivated learners in his class are likely to engage with the material. Those who are less intrinsically motivated are more strongly influenced by strategies the teacher uses to reach his students.

Information provided by learners on post-training surveys permits us to examine this explanation more closely. Learners were asked to identify their reasons for taking the course. They were provided with four checkboxes from which to select:

1. Assigned by my manager
2. Assigned by a learning advisor
3. Required for compliance
4. Wanted to learn about this topic

Learners could check more than one box, at their discretion. So a learner might be assigned a course by his manager and required to take that course for regulatory compliance, and that learner would check both the first and third boxes. Some 67% of learners in the sample checked a single box from the available four, and another 9% checked none of the boxes. This makes it plausible to examine the sample in terms of single-purpose learners while leaving aside the more complex issue of multiple motivations.

Learner motivation and comparison #1

Table 6 shows the five engagement measures for the two media combinations in Comparison #1. Table 7 then draws the comparison between those measures. The fifth row is particularly important. These are the engagement figures for learners who indicated they took the course because they wanted to, and who did not check the boxes indicating a manager or learning advisor assigned the course or that it was required for compliance. These can reasonably be viewed as self-starting or voluntary learners.

Table 6
Engagement for business skills courses by reason for taking the course

Media Combination	Course Type	<i>N</i>	Reason	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
FT + I	Business Skills	363	none	4.87	4.92	5.13	4.95	5.07
		411	Mgr.	5.15	5.13	5.18	5.27	4.94
		363	LA	4.45	4.51	4.53	4.42	4.28
		227	Compl.	5.24	5.23	5.17	5.21	5.04
		1,525	Vol.	5.80	5.74	5.58	5.44	5.92
A + PT + I		298	none	5.69	5.67	5.81	5.82	5.73
		577	Mgr.	5.36	5.33	5.54	5.54	5.32
		274	LA	5.39	5.38	5.69	5.59	5.27
		311	Compl.	5.43	5.47	5.66	5.64	5.29
		1,668	Vol.	5.78	5.76	5.85	5.79	5.92

Table 7
Comparison #1 for business skills courses by reason for taking the course

Comparison	Course Type	Reason	Good Experience	Met Needs	Job Applicability	Job Use	Take Another	
#1	FT + I A + PT + I	Business Skills	none	.82*	.75*	.68*	.87*	.66*
			Mgr.	.22*	.20*	.36*	.28*	.39*
			LA	.95*	.86*	1.17*	1.17*	1.00*
			Compl.	.19	.24	.49*	.42*	.25
			Vol.	-.02	.02	.27*	.36*	.00

Note to Table 7: Figures marked with an asterisk are statistically significant at the 95% confidence level in two-tailed t-tests.

Engagement was impacted very little by the application of cognitive pedagogy for the volunteer learner group. For the first two measures — overall reaction and whether the content met their needs — there is essentially no increase. For the third and fourth measures that reflect job applicability and ability to apply skills, there were modest but statistically significant increases.

All four of the other groups — those who were assigned training or who took it for compliance reasons — experienced greater engagement increases than the volunteer learner group. Learners who were assigned courses by learning advisors experienced an especially large increase, as did those employees who did not check a box to indicate their reason for taking the course.

Learner motivation and comparison #2

Table 8 shows the five engagement measures for the two media combinations in Comparison #2. Table 9 then draws the comparison between those measures. Business skills courses reveal a similar pattern to that seen with Comparison #1. There is no discernible engagement boost for volunteer learners. The numbers are virtually flat, or even slightly negative. Modest increases can be seen for those assigned to take the course by a learning advisor, those required to take it for compliance, and those who did not indicate a reason for taking the course. For these three learner segments, the most significant increases were measured in job applicability and perceived ability to apply the learned skills.

Table 8
Engagement for Business Skills and Compliance Courses by Reason

Media Combination	Course Type	<i>N</i>	Reason	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
A + FT + I	Business Skills	254	none	5.55	5.47	5.61	5.56	5.78
		350	Mgr.	5.34	5.36	5.47	5.38	5.24
		171	LA	5.33	5.25	5.38	5.29	5.09
		200	Compl.	5.25	5.35	5.52	5.41	5.02
		1,059	Vol.	5.82	5.76	5.90	5.78	5.99
	Compliance	96	none	5.33	5.61	5.70	5.59	4.83
		315	Mgr.	5.29	5.32	5.40	5.34	4.67
		85	LA	5.36	5.56	5.57	5.49	4.62
		613	Compl.	5.36	5.41	5.52	5.38	4.41
		82	Vol.	5.72	5.72	5.73	5.60	5.54
A + PT + I	Business Skills	298	none	5.69	5.67	5.81	5.82	5.73
		577	Mgr.	5.36	5.33	5.54	5.54	5.32
		274	LA	5.39	5.38	5.69	5.59	5.27
		311	Compl.	5.43	5.47	5.66	5.64	5.29
		1,668	Vol.	5.78	5.76	5.85	5.79	5.92
	Compliance	880	none	6.07	6.17	6.27	6.29	5.51
		3,830	Mgr.	6.17	6.20	6.28	6.26	5.53
		346	LA	6.18	6.17	6.24	6.22	5.40
		1,961	Compl.	6.15	6.20	6.27	6.31	5.32
		179	Vol.	6.21	6.23	6.39	6.35	5.84

Table 9
Comparison #2 for Business Skills and Compliance Courses

Comparison		Course Type	Reason	Good Experience	Met Needs	Job Applicability	Job Use	Take Another
#2	A + FT + I A + PT + I	Business Skills	none	.14	.20	.21	.26	-.06
			Mgr.	.02	-.02	.06	.16	.08
	LA		.06	.13	.31*	.30*	.18	
	Compl.		.18	.12	.14	.23	.27	
	Vol.		-.04	.00	-.04	.02	-.07	
	Compliance	none	.73*	.57*	.58*	.70*	.69	
		Mgr.	.88*	.88*	.88*	.92*	.86*	
		LA	.82*	.61*	.67*	.73*	.78*	
		Compl.	.79*	.79*	.76*	.93*	.91*	
		Vol.	.49*	.51*	.66*	.75*	.31	

Note to Table 9: Figures marked with an asterisk are statistically significant at the 95% confidence level in two-tailed t-tests.

For compliance courses, engagement was boosted significantly for all five learner segments. Volunteer learners had the lowest increases of any segment, but increases for all segments were substantial. The three other segments (those who were assigned or required to take the course) showed significantly greater increases, as did the segment that did not identify a reason for taking the course. The overall pattern is similar, with the caveat that self-identified volunteer learners experienced a limited boost. One possible explanation is that the compliance category of courses is inherently focused on job requirements, so the self-identified volunteer segment may still view the content as focused on requirements in the workplace.

Discussion

The two comparisons drawn in this study may be thought of as two stages in the improvement of courseware pedagogy. The first stage involves adding audio, and the second involves taking away most on-screen text after audio has been added, so language content flows through the more capable auditory channel. The second stage in this process is particularly interesting, because it can present certain challenges for some learners. Prior to this stage, a learner can page through a course and have the full content presented to the learner visually. After the evolution toward limited on-screen text, the learner can only experience the full content by spending time on each page and listening to audio as related imagery displays. At this stage, audio is necessary to access content, and since audio cannot be scanned readily in the manner of on-screen text or imagery, this introduces a time component to the learning experience.

Some learners could argue that they prefer to scan courses in search of information that is new or relevant. On the other hand, adoption of this second evolutionary stage tends to diminish one of the major concerns of eLearning providers — the reality that some learners page through courses

without engaging the content to any significant degree. The second stage makes rapid page-throughs difficult to apply as a learning strategy.

The findings in this study provide some guidance on the impact of each of these two evolutionary stages on learner engagement. The broad pool of learners who are assigned or required to take courses experiences a large engagement boost when moving from earlier design stages that made no audio available to advanced design stages that use full audio and limited on-screen text. The smaller segment of intrinsically motivated or volunteer learners experience little increase in engagement, although there are modest increases in job applicability and anticipated ability to apply the learned skills.

A similar pattern emerges in moving from the initial audio stage, where full text is still provided, to the second stage where most text is removed from the screen. For business skills courses, a modest boost in engagement is measured for the broad pool of learners and essentially no boost for volunteer learners. For compliance courses, a boost is detected for all learners, with the smallest increase occurring in the volunteer group and larger increases in the broader pool of learners.

Intrinsically motivated learners appear to experience either no boost or a modest engagement boost with the application of cognitive pedagogies to content pages. They have no discernible preference for the early text-heavy instructional designs that can be scanned more readily, and, at times, a modest preference for the more evolved designs. By comparison, the larger pool of externally motivated learners experience strong engagement boosts with the new designs.

In general, these results suggest that the application of cognitive learning principles substantially broadens the reach of eLearning courseware. The multiple representation and split-attention principles can be applied by instructional designers to successfully engage a broad pool of learners who arrive at training with external rather than internal motivations.

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