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EXTENDED PAPER

Redundant layers of efficient media communication.
Why communication seems to be stable and the media is not

Kommunikative Effizienz durch redundante Medien.
Warum Kommunikation stabil erscheint,
die Medien es aber nicht sind

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To Arnulf Kutsch, the distinguished scholar of historic-systematic communication science

Abstract: This paper promotes an integrative concept of information, communication and media (ICM). It scrutinizes the change, stability and impact of ICM with regards to efficiency, effectiveness and redundancy: Media evolution is driven by efficiency; evolution triggered enhanced effectiveness (in information processing) and has created redundant layers of media. The most important basic innovations in the evolution of human communication are *Proto Media* (mainly language), *Basic Media* (writing and painting) and *Dissemination Media* (from press to social media): these three stages of media evolution provide a ratchet effect that prevents society from fall backs. Supposedly, redundancy bridges time – in its different forms and on different levels. Nevertheless, the past, present and future are not deterministic. On the contrary, the efficiency argument provides logical proof that evolution is an open (nondeterministic) process.

Keywords: Media evolution, effectiveness of information processing, redundant layers of communication, non-determinism (contingency) of history.

Zusammenfassung: In dem Beitrag wird ein integratives Konzept zu Information, Kommunikation und Medien (IKM) vorgeschlagen. Stabilität, Wandel und Wirkung der IKM werden mit drei Begriffen analysiert: Effizienz, Effektivität und Redundanz. In dem Streben nach Effizienz ist die Ursache der Evolution von Kommunikation und Medien zu suchen, die zu einer redundanten, mehrfach ineinander geschachtelten Abfolge der Medien führte. Die Medien- und Kommunikationsevolution löste dabei eine mehrmals deutlich gesteigerte Effektivität in der Informationsverarbeitung aus. Die drei wichtigsten Basis-Innovationen dieses Prozesses waren die Entwicklung der *Proto-Medien* (v.a. der Sprache), der *Basis-Medien* (Schrift und Bild-Symbolik) und der *Verbreitungs-Medien* (von der Presse bis zu den „Sozialen Medien“). Dank dieser Basis-Innovationen hat sich die Menschheit eine eingebaute Rückfallsicherung gegen Kulturverlust erworben; sie bedarf aber steter, redundanter Aktualisierung. Diese Redundanz – beginnend schon auf sprachlicher Ebene – ist mutmaßlich die entscheidende Brücke über die Zeit (vom Gestern ins Morgen). Gleichwohl

kann von determiniertem (z.B. technik-determiniertem) Wandel nicht die Rede sein; im Gegenteil, das Effizienzargument führt zu einem logischen Beweis, dass Geschichte bzw. kulturelle Evolution ein offener (nichtdeterminierter) Prozess ist.

Schlagwörter: Medienwandel, Effektivität der Informationsverarbeitung, redundante Schichten der Kommunikation, Kontingenz der Geschichte.

1. Preliminary remarks[1]

Media, information and communication cause exchange, change and stability; they provide the fundamentals of human society: when media and communication are two sides of the same medal, information is its rim. While media is one of the most rapidly changing features of the modern era, communication as such has to be stable – and information provides the data for society's decisions. What media, which communication and what information am I talking about?

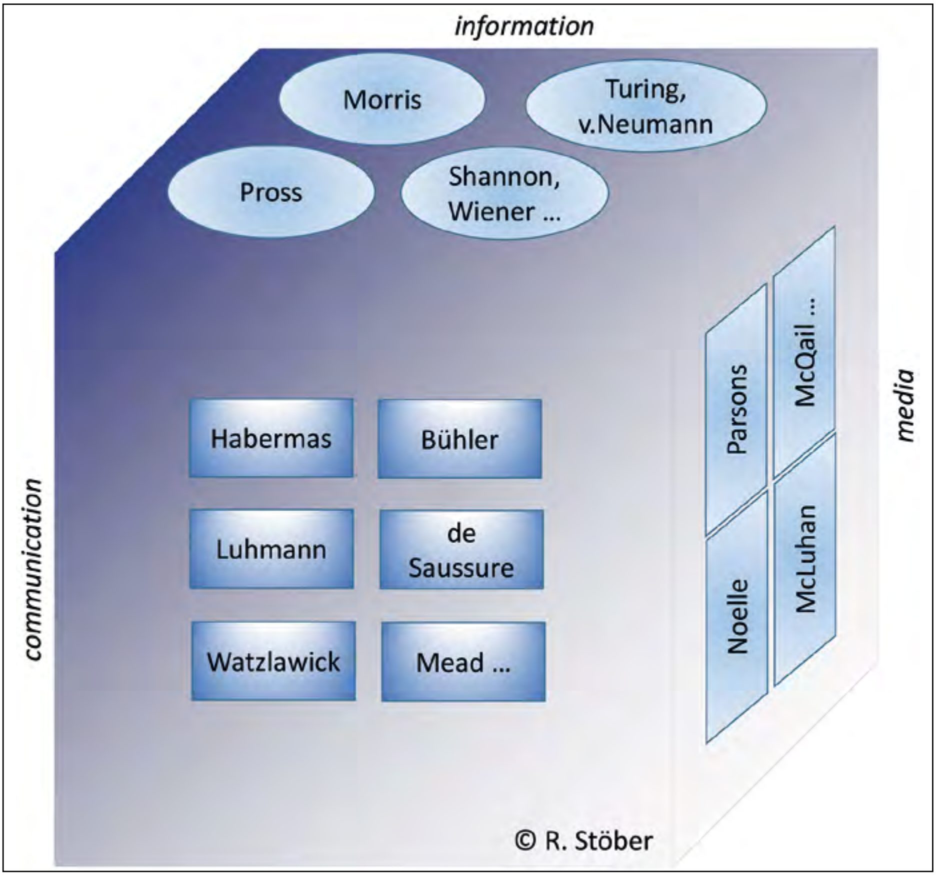
Different notions of communication, information and media
In communication studies, when related to social sciences, media is often used as a synonym for *mass media* or *dissemination media*. In media studies, when affiliated with literature studies, many scholars refer to McLuhan (1964): media as "extensions of man." Sociology and other more generalized approaches prefer an even wider notion: for example, when Parsons meant common instruments of exchange, he referred to "generalized media" (Parsons, 1963).

Theories of communication differ even more strongly: Sometimes, communication is equivalent to *behavior* (Palo Alto School [Watzlawick, Beavin and Jackson 1962]). Sometimes it means *social behavior* (George H. Mead [1934] and other theorists of social behaviorism). Occasionally, the notion has the meaning of *mutual understanding and social action* (Jürgen Habermas [1981] and other theorists of social action). For other scholars, communication is an *essential function of societies* (Niklas Luhmann [1984] and other system theorists). Some scholars use the notion as a *simile for language and speech acts* (de Saussure [1916], Bühler [1934], and other linguists and speech act theoreticians).

Information is a third and much disputed notion: Some concepts of information are equivalent to "news" (Harry Pross [1977] and common understanding in communication studies). Then information is equal to *symbols* (semiotics like Charles Morris [1938 and 1970] and others). Finally, information is the fundamental notion of the *mathematical information theory* (Claude Shannon [1948], Norbert Wiener [1948] and others). An objective of this paper is, therefore, to develop an integrative concept of information, media and communication.

1 The article summarizes, extends and reconsiders some former publications of mine (2004; 2008; 2011; 2013; 2014a and 2014b). Furthermore, it adds some examples to the former reasoning. I gratefully thank all the colleagues, who gave comments on the former publications and on the raw version of this one, namely Helmut Glück, Carsten Wünsch and Gunda. Also I'd like to thank the unknown peer reviewers; the critics helped me to sharpen the reasoning without changing its essence.

Figure 1: Different notions of communication, information and media



The different concepts and notions refer to the same problem: What is the use of information, communication and media? This paper will examine where the different notions and concepts converge. The interlocking is complex; many concepts encapsulate one another; communication, information and media refer to one another redundantly in different layers; they provide efficiency and effectiveness. Efficiency is seen here as the driving force of change, and redundancy as its safeguard, especially in the modern digital world: while the introspection into layers of information proves the redundant stability of communication, efficiency explains the media change. This makes ICM highly effective.

The article introduces formalism (do not worry: with one exception, only in the notes). The idealized terms shall underline the reasoning: On the one hand, the terms serve as a quasi-mathematical aggregate of the argument; on the other hand, the terms provide an undisputable proof (especially the limit terms). Furthermore, the terms point to the philosophical debate whether or not algorithms can express reality as such. This paper will strictly discriminate between a mathematical approach in theory and practice: The ineptness of a total mathematical description of reality does not prevent us from reasoning with formal instruments. While Gödel proved that logically (Gödel, 1931), in practice, every approach of total mathematical description will fail – due to the incompleteness of information.

Table 1: Some suggestions in brief (to be proven by this paper)

Some questions ...	*and answers*
What is the driving force of change?	Efficiency drives change. Every emerging step creates a new layer on the evolutionary path.
What is the main consequence of every new layer of evolution?	Every new layer provides more effectiveness and an enhanced reach for resources.
Why are humans able to make use of new media, even without proper training?	The layer by layer construction of media is the base of media competencies; the use of every new media starts with proven practices; old media competencies are incorporated; the *new* in new media is a functional surplus.
Besides the constant change: what provides the necessary stability in time, space and society?	Logically, there is no change without complementary stability. Redundancy provides the necessary stability over time: the consequences affect everything, mind and matter, media infrastructures, communication, culture, social entities and individuals.
Why can no one predict the future precisely?	The progress of efficiency is limited; after reaching its specific limit the game changes, sooner or later; neither the exact point of time nor the trajectory of the transformation will ever be clear in advance.
What is the role of technology in the change of communication, information and media?	Technology (technological inventions) provides opportunities and options.
What is not the role of technology?	Technological opportunities do not have to be seen, options do not have to be taken. There is no deterministic pathway of causes and consequences driven by technology.
What is the role of society in the change of communication, information and media?	Society is the (great) decision maker: society decides whether or not opportunities have to be taken; society decides when the options will be taken; society decides which one of the possible options will be taken.
What is not the role of society?	Society, normally, does not introduce a master plan of cultural evolution. Plans planned and considerations discussed do not deeply influence the standard procedure of cultural evolution: that usually consists of tinkering (trial and error).
An additional question: Why do most humans prefer the convenient way rather than the inconvenient?	The convenient way of living seems to be more efficient, at least for a short period. Any work and hardship is, from the evolutionary point of view, a waste of energy. Therefore, most humans try to avoid it. Nevertheless, inconvenience often pays back in the future; work and investments are efficient in the long run.
And last one: What are the objectives of this article?	This article has three objectives: a logical, a theoretical and an empirical one. Logically, it reasons about the cause of change and stability. Theoretically, it is an attempt to integrate considerations on information and communication into media theories – including media infrastructure theories. Empirically, it provides a base for input-output calculations of media change.

Thus, the logic of efficiency provides the formal proof for why an input of individual rational choices will never offer a projectable outcome for society; because efficiency has its natural limits, every pure rational choice theory will lead us astray. The consequence seems trivial at first sight: some things will change and others will remain stable. At a second glance that may be everything, but not trivial: The interaction of change and stability causes future's opaqueness; at the end, the limits of efficiency provide another logical proof[2] for the unpredictability of evolving systems.

The article starts with some observations on media layers. Then, it will look into communication more deeply. Another step will examine the driving forces behind evolutionary change and calculate some examples of media's efficiency and effectiveness. Finally, conclusions and further considerations on the ratchet function of media, on media's longevity and on the limits of my reasoning will finish the article.

2. Observations: Layers of media

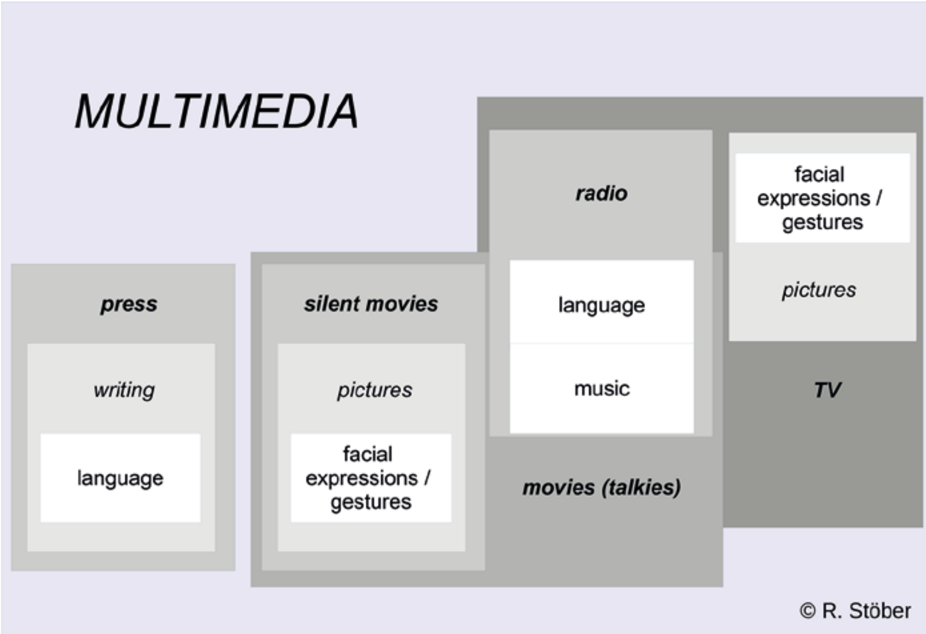
2.1 Inclusions provide media competencies

Nowadays, digital media dominate; the terms "multimedia" and "hypermedia" are also in use. The notions lay stress on the fact that modern digital media include many (if not all) of the older media: TV, press, letters, books, films, etc. Digital media include mass media for dissemination purposes and individual media for individual social reasons. One can imagine media as a set of Russian nesting dolls (babooshkas, matroshkas): they include one another. In technical and cultural terms, the talkies (movies with sound) combined radio and silent movies; TV is a combination of sound cinema with radio dissemination; and the press, radio, TV and films are integrated into multimedia.

The integration reaches even deeper: through a sequence of inclusions. The cascade depends on different media competencies. Figure 2 gives simplified examples: no one can use the press without capabilities in reading and writing; the knowledge of the specific language of the newspaper is also necessary. No one can learn from a film without decoding the symbols, the pictures and the facial expressions and gestures of the actors. If one is watching a silent movie, the ability to read intertitles is necessary, too. If listening to radio, you have to understand language and appreciate music. Journalists, film producers, actors in TV and in the movies, radio announcers (and all the other professionals dealing with media) have to have an active communication repertoire for media purposes: the communication and reception of media depends on different media competencies. For instance, the competencies are not isolated TV- or film-makers' skills; instead, the expertise consists of different layers of competencies: The base concerns language and gestures. Elaborated competencies concern writing and reading. For specific media, very special competencies in communication and reception are required.

2 That is, besides quantum mechanics and diverse historical-philosophical reasoning on the opaqueness of the future.

Figure 2: The inclusion of media in multimedia



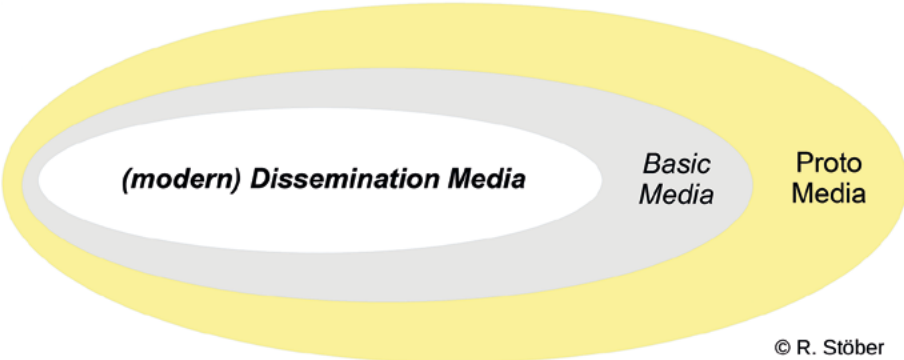
In figure 2, neither the variety of media competencies nor the inclusion of media is perfect. The same fonts indicate that the layers of media are equal in an abstract way. Some media are typeset in bold italics: press, silent movies, talkies, radio, TV and (in capital letters) multimedia; the media in that cluster are *Dissemination Media*. The media in the next layer are typeset in bold types: writing and pictures are called *Basic Media*. Another layer consists of language, facial expressions, gestures and music; these *Proto Media* are typeset in normal types.

Three clusters of different layers of media reach back from the present to an ancient past. *Dissemination Media*, mostly mass media, is the youngest cluster. At the beginning of modern media stands the press; multimedia are the media of today. The media in between – *Basic Media*, mainly writing, painting and other forms of symbols – are connected with the dawn of (high) cultures. The core of human communication – *Proto Media* – reaches still deeper; it is interaction through gestures and language; these quasi-media obviously arose from a long lasting and continuous striving for better social contact. *Proto Media* – as means of human behavior – enable communication; *Basic Media* preserve it over space and time; modern *Dissemination Media* provide us with the most effective form of spreading the news.

Figure 2 suggests that the most modern media include *Proto Media* and *Basic Media*; however, it is the other way around; all modern media provide humanity with specializations of the dissemination of written and painted symbols. Understanding language and writing, as well as de- and encoding of other symbols provide important competencies for many different media. Modern *Dissemination*

Media take part in the oldest forms of human communication: language and gestures. They also use younger cultural techniques: writing and painting. Therefore, every specialization of media integrates new communication technologies into older social and cultural functionalities. The improvement of communication techniques extended the reach of our oldest means of communication: modern *Dissemination Media* are part of *Basic Media*; *Basic Media* (writing, handling of complex symbols, pictures) are part of *Proto Media* (language, gestures). With every layer, the level of information processing expands.

Figure 3: The inclusion of media forms in Proto Media



2.2 Redundant inclusions provide media's effectiveness

On the one hand, the inclusion of media in other media[3] is a multiple-redundant strategy; on the other, it is useful, efficient and effective. Effects and efficiency may be closely related, but they are not the same. Peter F. Drucker (1963) underlined that long ago. Efficiency describes an input-output relationship, effectiveness refers to the impact: The question of whether media have an impact is a question of effectiveness; whether media impact is weak or strong is a question of media's efficiency.

Proto Media provided early humans with the skill to educate their offspring. Furthermore, communication through language and gestures enabled Neolithic tribes to gather and share information on food and other resources. Finally and importantly, the earliest means of communication included warning signals in situations of jeopardy. Even if we do not fully understand the mechanism of the appearance of language, according to Mead (1934), Morris (1938 and 1970), Wilson (2012) and other scientists, we can assume that the development of language intertwined with the genesis of a "theory of mind." That is, the development of communication and the growth of both the human brain and the intellectual capacity of man mutually affected each other. Both symbol manipulation

3 Formally noted, Term 1: inclusion model of media into media
Modern Dissemination Media $\subseteq$ *Basic Media* $\subseteq$ *Proto Media*.

capacities and representations of the real and the social world enhance man's ability to solve (and create) problems. Therefore, without *Proto Media*, no social life and no humankind as such would have evolved.

Basic Media provided further advantages in efficiency and effectiveness: According to Innis (Innis, 1951) and other theorists, writing, painting and mathematical symbol manipulation started with the high culture societies. *Basic Media* transformed acoustic into optical information and that is easy to store. This had a tremendous effect: Religion, history, and tradition did depend no more on storytelling. High cultures mastered space and time with their advanced communication techniques; they gained great advantages over illiterate cultures, including the ability to provide administration. Professional writers, the earliest administrative staff, managed administration by virtualization. Symbols preserved laws and society's rules, information gathering, news distribution and finally, yet importantly, routines in state affairs. At least some redundant routines transformed into rituals.

Modern *Dissemination Media* increased the efficiency and effectiveness of information processing (input, throughput, output) further. It granted wider access to information; it did so by a parallel decrease of information costs. Today, information transport is faster than any other media since Gutenberg; transport velocity has accelerated from years, months or weeks to real time information: without modern media, the social, political and cultural forms of interaction would slow down tremendously. Modern *Dissemination Media* provide a constant torrent of information; information's quickness and steadiness have established new forms of the public: without the digital infrastructure, neither can simultaneous worldwide stock markets nor social media exist.

2.3 New media include and enhance old media

Media innovation emerges from improvements of old media. It is evident that neither was *new media* invented at once nor were the inventions planned. Chapter 4 proves the inevitability of an unpredictable outcome. The obvious facts are these: The creation of new means of communication followed a long and winding path of institutionalization. For example, the new medium *periodical press* derived from the old medium *writing* by a step in between: the printing of books and leaflets. The new medium film (storytelling motion pictures) emerged from older entertainment media by surpassing early films as another vaudeville amusement. Radio broadcasting with its one-to-all mode arose from the older media telegraphy by exceeding the one-to-one mode of wireless telegraphy. The multi-useful WWW and modern social media extended an early Internet for military purposes; the early Internet enhanced a centralized telephone and telegraph infrastructure.

The starting point of new media, although unplanned, was the observation of efficiency deficits. The momentum of planning hinted at the improvement of *old media*: Technical inventions made old media more efficient; Johannes Gutenberg did not invent the printing press, but he invented printing with removable letters. He made writing and copying more efficient. Gutenberg aimed primarily at the market of very expensive books. Electrical telegraphy improved optical telegraphy. Alexander Graham Bell announced his invention of the telephone as an "improvement in telegraphy." Early films looked like vaudeville and variety amusement. Therefore, film is a perfection of older optical media, such as the laterna magica, moving panorama, etc. Radiotelegraphy seemed to fit better for some aspects of one-to-one communication than wired telegraphy, especially in communication with ships and colonies. Television appeared to improve telephony by adding optical information. The Cold War scheme "Advanced Research Projects Agency Network" (ARPANET) had to guarantee stable communication by redundant telegraphy, telephony and computer communication in case of a nuclear attack. When mobile phones came up in the late 20th century, everybody saw them as wireless telephones, but they have become the basis for the use of social media. In general, the beginning of each new invention was the improvement of an old cultural technique: with respect to social life, inventions erased deficits rather than created new forms of communication.

Therefore, some scholars suggest that change is driven by technology. Despite the evangelists of technic determinism, as research on diffusion suggests in general, the public wants to be convinced by the usefulness of a new technique before it becomes widely accepted (cf. Rogers, 2003; Dogruel, 2013). It seems evident that society decides, which one of the possible options of this invention will be taken: An innovation emerges, when it offers a functional surplus. This has been explained in more detail elsewhere (Stöber, 2004).

For our purposes, it is noteworthy that the efficiency of improvements is a matter of perspective; efficiency is quite meaningless on its own; improvements all have their specific point of reference. Or rephrasing that: efficiency counts, but compared to what? To exemplify the changing of reference points, printing as such is not faster than writing. In general, the printing process for the first copy takes longer than writing the same text. So printing (á la Gutenberg) is inefficient in the mode of *one-to-one* communication, but it becomes more efficient the more copies are made. Printing gains advantages in the communication mode of *one-to-many*. Therefore, the press is very efficient for mass communication purposes – that is, for a reference point of *one-to-many*; as long as the point of reference is *one-to-one*, writing may be a more convenient mode of communication.

Table 2: Improvements of old and emergence of new media

	invention (1st step): improvements of an old medium	*innovation (2nd step): development and emergence of new media*	*diffusion (3rd step): differentiation and dissemination of new media*
printing	improvements in writing	development of serial (and quasi-serial) press	differentiation into broadsheets, newspapers, magazines, etc.
electrical telegraphy	optical telegraphy for political and military purposes	media for private and economic purposes	news agencies, stock market information, railroad coordination
telephony	telegraphy	one-to-one medium for business and private purposes	(failed) differentiation into music, theater and news programs
film	vaudeville and variety amusement	development of program media with newsreels and movies	genres (incl. meta- and sub-genres)
wireless telegraphy/radio	wire based telegraphy	broadcasting entertainment and information programs	radio formats
television	telephony	broadcasting combined with film	TV formats
computing/ multimedia	devices for more efficient calculation	multipurpose devices	social networks

The points of reference transform with the change of media. Small changes may occur with improvements of the old media, but big changes only derive from the creation of a new media: Only new media are game changers, for they enhance the reach of communication far beyond the former scope of information processing. The enhancement of reach has to be described more fundamentally; that is necessary, too, for the new points of reference that start new competitions for efficiency advantages (inscribed in different media layers). While the subsets of media layers repeat older media forms, they are grounded in redundancy. Where do the supposed redundancies of media layers take root? A closer look of the deeper layers of communication is necessary (cf. chapter 3). Where does efficiency come from? Where will enhanced effectiveness lead? Scrutiny of the specific characteristics of the efficiency claim follows (cf. chapter 4).

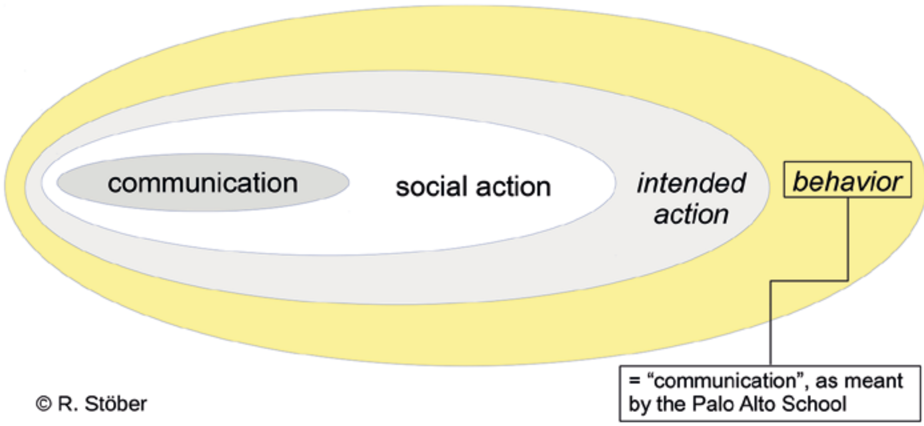
3. Introspection: Layers of communication

3.1 Maybe communication is not inevitable – but it is effective

As we learned from Watzlawick, Beavin and Jackson, communication is inevitable (1962, p. 32). However, a closer look at the famous saying – "one cannot not communicate" – reveals that Watzlawick, Beavin and Jackson meant behavior, not communication; everyone and everything "behaves." Behavior is not a matter of consciousness and intention. According to Max Weber, behavior changes to action through the "actor's" intention. Thus, intended action is a part of behavior.

Supposing that a human being is interacting with other members of the community, Weber declared this as "social action". The set of "social actions" is a subset of the set of possible intended actions (Weber, 1980 [1921/22], p. 1). We can extend Weber's set of inclusions by another: Communication is a special form of social action.[4] There is another set of subsets: communication is included in social action; social action is a part of intended action and that is a subset of behavior. Figure 4 illustrates this; it can be written as a term of subsets, too.[5]

Figure 4: The inclusion of communication in forms of action and behavior



Any action with an impact is effective by definition. Behavior may be inevitable, but it cannot preserve social understanding *per se*. Intended action may be better for doing the job. Social action may be one step better than intended action. At last, only communication provides the task: Communication is more efficient and more effective than any other form of social action. Nevertheless, communication means labor and effort, in some way or the other, and from an action-theoretical point of view: successful communication is not an automatic process. With respect to Georg Simmel, one could claim that the question "How is communication possible?" is the most important in communication science.[6] Communication is strenuous.[7] That is, . . .

4 Sometimes social action is regarded as a subset of communication (cf. Sommer, 2014). In fact, it is difficult to discriminate between both notions. Man's forms of social action are difficult to perceive without communication. Nevertheless, I suggest the inclusion of communication in social action. For example, one might cook a meal for more than two people. From an outcome perspective, this would definitely be a social action; much communication may arise from the meal, later; but the cooking, as such, cannot be subsumed into communication.

5 Term 2: inclusion model of communication into action and behavior
Communication $\subseteq$ *social action* $\subseteq$ *intended action* $\subseteq$ *behavior*.

6 The sociologist Georg Simmel once labeled the question "How is society possible?" to be the most crucial question of social sciences (Simmel, 1908, pp. 22–30).

7 Social action preserves a community better than nonsocial, but intended actions. What works better for the maintenance of individual social relations than communication? On larger scale it's the same with societies.

3.2 Communication as a shortcut in space and time

. . . Communication is not effortless. At least, that is apparent for communication in its wider meaning. Today's most common meaning refers to an information transfer process. A hundred years ago, "communication" was connected more prominently to different meanings. The notion primarily referred to intercourse, commerce and personal forms of contact.[8] According to Merriam Webster's Dictionary, these meanings are not completely out of use, yet.

There are some points for the use of communication – in its older meaning – as a proxy for communication's effectiveness and efficiency: Transport infrastructures mark the beginning of public services in advanced societies. Of course, until present days, some infrastructure buildings cost tolls and fees. Both kinds of financing (private and public) provide examples for the refinancing of media. Furthermore, investments in transport infrastructures may serve as examples for communication's strains.

8 Notions change their meanings; sometimes they become wider, sometimes they become narrower over the course of time. In German, the secondary meanings of "communication" are out of use, nowadays, however, they were the primary meanings 100 years ago.

Table 3: The effectiveness and efficiency of infrastructure

example	*calculations*	*explanations*
Traffic jam caused by breakdown of the Schierstein Bridge	1 minute (normal crossing time) * 80 000 (cars) = *55.5 days* of crossing time a day. Between 20 minutes and 2 h extra traffic jam time * 80 000 (cars) = range of *3 years to 18.3 years* of crossing time delay every day. The cumulative time delay caused by traffic jams over 8 weeks of breakdown: from *168 years* up to *1 025 years*. The *income loss* caused by the cumulative time delay ranges from *3.4 to 20.5 MM €*. Therefore, and at the worst, the breakdown of the bridge added up to more than 40% of the costs of the original building; at best, it costs 7%. Even when compared with today's renewal costs, the cumulative loss added up to 10%, at worst.	On February 11, 2015, an important bridge in the Rhine-Main area of Germany was severely damaged and closed for reconstruction. Exactly two months later, the bridge was reopened for cars. The length of the bridge is 1 282 m – ramps included. At the speed of 80 km/h that means a crossing time of (a little bit more than) 1 minute. Approximately 3 000 cars a day used a ferry over the Rhine during the bridge closure.[9] At best, the closure meant a 20 minute time delay; at worst, some commuters lost 4 hours of extra time from home to office and back.[10] 80 000 cars, lorries and motorcycles (40 000 in either direction) cross the bridge every day. The original construction cost 32 MM DM in 1962; in today's prices, that is ca. 50 MM €. The re-erection of a new bridge that started in 2013 was calculated to cost more than 200 MM €. According to the German Bureau of Statistics, the present median income of a household is more than 20 000 €.[11]
Bridge shortcut	A bridge made the way for commuters 56 km shorter; in 22 years since construction this saved 1 533 years of the commuters' cumulative lifetime.	This example is from the film "Margin Call" with Kevin Spacey. The ex-banker Eric Dale (actor: Stanley Tucci) makes up that calculation. In his former film-life, Dale was a construction engineer.
Visit to Washington by airplane instead of mass media use	1 000 people * 9 h flight time (one way) = one year of cumulative lifetime; that is, almost 100 000 people lose an accumulated lifetime on their visit to Washington, which is equal to a human life. And they have to come back home, too. Therefore, the accumulated lifetime of approximately 50 000 people onboard equals a human life.	Consider a paradox world without mass media but with modern travel infrastructure; people would have to personally go to a place where something was going to happen, for example, the inauguration of a new US president. The calculation is generous. It does not include delay caused by immigration procedures, standby time before take-off, etc.

The first example calculates disadvantages: What does the loss of time and money mean, when the infrastructure breaks down? The second example calculates advantages: What surplus is derived from the investment in infrastructure? The third example compares the costs of face-to-face communication with virtual communication: How dear is the existence of modern media infrastructure? All three examples have incomplete information. For the first, we do not know the total loss of the Rhine-Main economy. For the second, we cannot calculate the costs of the erection of the fictional bridge. For the third, many costs (fuel, maintenance of airplanes, costs of airports, media infrastructure costs and so on) are unknown.

The examples of bridges and other traffic infrastructure provide analogies. First, media, communication, and the given examples bring people in closer relationship to one another. Second, the examples cause effort and strain, but the "work's" outcome provides advantages (in gains of time, money, convenience); with media and communication, this is the same. Third, advantages and, in case of interruption, disadvantages may be hidden from normal reasoning, but they become visible under special circumstances; that also takes time. Fourth, infrastructure is hardwired communication; its construction is not trivial. So is communication in its more common (and narrower) sense: complex construction provides the basis of media layers.

3.3 Communication's effectiveness is due to its layers

The effectiveness of communication "is bought" by complex construction rules: Communication refers to a construction code that consists of rules on different levels (and for different layers). I will discuss the rules by discussing language. That is for two pragmatic reasons: on the one hand, linguistic research is far more advanced than any other research on prototypical communication means; for example, it is more advanced than research on facial expressions or gestures. On the other hand, it is much easier to describe language using a formal approach than it is for any other basic form of human communication. The following considerations, nevertheless, can theoretically be extended toward gestures and facial expressions.

Communication by language is loaded with (semantic) meaning by convention and mutual understanding. Linguistics, especially in speech act theory, deals with these rules. There are many theories worth mentioning. As divergent as they are, for our purposes it is sufficient to notice that speech act theories from Bühler to Austin, Searle and Habermas have two things in common: first, all of the theorists underline the importance of the social act of communication; second, the varia-

9 http://www.faz.net/aktuell/rhein-main/schiersteiner-bruecke-offen-faehrbetrieb-ueber-rhein-entfaellt-13550438.html (August 31, 2015).

10 http://www.faz.net/aktuell/rhein-main/schiersteiner-bruecke-volle-zuege-nach-der-sperrung-13425125.html and http://www.faz.net/aktuell/rhein-main/leben-mit-der-verkehrsbehinderung-schiersteiner-bruecke-13534873.html (August 31, 2015).

11 According to http://de.wikipedia.org/wiki/Schiersteiner_Brücke and compared with statistics from "Datenreport 2013" http://www.bpb.de/nachschlagen/datenreport-2013/ (August 31, 2015).

tions of theories prove the abundance of premises necessary for mutual understanding.

The premises of communication shall be illustrated by taking a closer look from the perspective of symbol manipulation. The core of communication is information processing. Every human language consists of a discrete set of symbols (of 1st and 2nd order) combined with a finite set of rules. The set of rules has semantic, syntactic and pragmatic dimensions.[12] The set of rules in combination with the finite set of symbols enables every speaker of any given language to perform an infinite multitude of possible communications.[13]

Examples for the infinite

Thus, Jorge Luis Borges' proverbial "library of Babel" potentially comes into existence: Every thought, sentence or book might be possible, regardless, whether or not it has come into existence until now, and regardless, whether the text makes sense or not.[14] We can envision nonsense combinations, word by word, sentence by sentence, chapter by chapter. For example, "a tree bites a dog": the sentence's words and grammar are OK, its meaning is not. Sentences or chapters from the works of Bourdieu, Giddens, Habermas and Luhmann might be combined, one by one. Every sentence or chapter in itself is reasonable, the combination as a whole is not. Therefore, the word building, sentence building and accidental text combinations, do not necessarily provide sense and therefore do not guarantee the beginning of communication.

The infinite variety of communication is the pragmatic representation of limitless reasoning, imagination and discoveries: Through languages, humans can imagine without limits; they can enact any cultural, social or technological change within their reach. It is not quite clear where this will lead. Natural human languages have led to Shakespeare, Goethe; music has led to Mozart; mathematical languages, especially in informatics, might lead us – for better or worse – to the singularity of Artificial Intelligence (AI) (cf. Kurzweil, 2005).

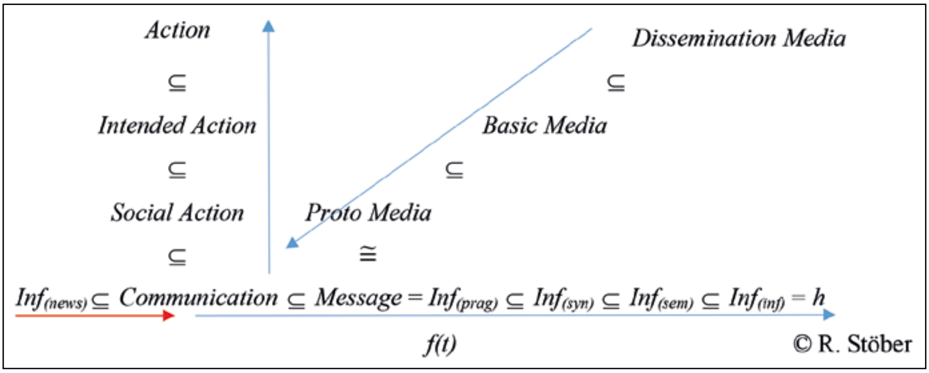
12 The details in question are controversial, but the general line is not. In general, the outlines of Noam Chomsky's generative grammar are accepted, still (Chomsky, 1965). Therefore, I will restrict myself to a simplified model of language construction. I will omit questions concerning restricted codes.

13 The infinite multitude of possible communications is usually expressed by the logarithmic measure of entropy. For a binary (digital) message, that would be n number of symbols to the logarithmic base of 2: $h = {}_2log^n$. Given a chain of 4 letters, taken out of the Latin alphabet of 26 letters (here simplified to just the small letters, excluding capital letters or letters with diacritic or any other marks), the number would sum up to 456 976 possible combinations: $N= {}_{26}log^4$. Its probability would be 1/456 976. This text with approximately 150 000 characters (in ANSI code: 256 different digital bytes) would sum up to $256^{150\,000}$ possibilities of symbol combinations. In digital bits: $2^{(150\,000\,*\,8)}$. That is pretty much more than my computer can calculate.

14 The infinite option of literary texts is similar to Alan Turing's reasoning "on computable numbers" (Turing, 1936, 1937). One can express the infinite options of texts with Term 3:

$N = \sum_{i->(a-z)}^{n->\infty} s_p$. That is, the probability p of each sign s – here as the specific information i of the alphabet (a-z) – and the length of the text (in theory also infinite) make the infinite outcome of the whole thesaurus of texts N. This will be explained in detail in the next two chapters (cf. 3.4 and 3.5).

Figure 5: Three dimensions of the inclusion of communication into action, information and media



Note: The arrows indicate the directions of inclusion: from specification to generalization.

An "action theory-perspective" on communication and an "information theory-approach" on the same matter refer to different dimensions of communication; both share the same pivotal point; an orthogonal switch combines both approaches. While the line in figure 5 refers to aspects of symbol manipulation, the column necessarily requires (human) interaction. The diagonal line is related to media; chapter 2 has described the inclusions of media. The vertical column is closer to effectiveness and efficiency; described in chapter 3 (above), it shall be continued in chapter 4. The dimension, which the horizontal line refers to, implies redundancies of different orders; it shall be described next.

The visualization of different inclusions comes with some uncertainties. For example, *Proto Media* is not equal but similar to pragmatic information (messages). Furthermore, communication is not equal to *one* message but to *different* messages; that exchange (by at least two people) constitutes communication. Information as such is a function of time (cf. next section); that is most apparent with the news aspect of information. However, news is beyond the point of interception of the three dimensions. Nevertheless, news is an integral part of the game. Finally, no dimension exists out of time, which leads us to the next section.

3.4 Level 1: Information as a function of time

Norbert Wiener once declared, "information is information, not matter or energy" (1948 [1965], p. 132). He regarded information as a function of time: *Inf* = *f(t)* (Wiener, 1948 [1965], pp. 75, 178). He meant that it is irrelevant whether the starting point of any specific information chain is at *t* or *t*'; from a formal point of view, it is irrelevant whether a sentence is uttered now or then. Furthermore, every information chain consists of information bits and has to be subsequently added to over a given time. Shannon (1948, p. 1) called the smallest elements of information (digital) bits. Information consists of them; when added in a finite set of time, information bits add up to more complex forms of communication. At last, communication provides society.

In a high-level information system, the smallest elements may be decimal numbers or alphabetical letters. Bits, numbers and letters are often called 1st order symbols. 1st order symbols have just one explicit meaning. 1st order symbols differ from 2nd order symbols (words).[15]

One can discriminate between different forms of information. Information, as defined in Shannon's and Wiener's information theories, shall be labelled $Inf_{(inf)}$. Information, as in any given natural language, is information of the 2nd order. In linguistics, information is separated threefold into semantic, syntactical and pragmatic aspects; here, they are notated $Inf_{(sem)}$, $Inf_{(syn)}$ and $Inf_{(prag)}$ (i.e., messages). Communication science deals with information of the 3rd order. That is, any information that provides news; news always compensates for a specific lack of knowledge; this information shall be called $Inf_{(news)}$.

Information theory's notion of information is rather irrelevant to communication science. Nevertheless, it forms the technical basis of the digital culture. $Inf_{(inf)}$ has been defined as negative entropy: $Inf_{(inf)} = -H$. Since Shannon and Wiener, $Inf_{(inf)}$ is a measure for storage capacity, channel capacity and all kinds of information probabilities. Paradoxically, the maximum storage h of any given system is equivalent to its maximum entropy: $h_{max} = +/-H_{max}$. Because the maximum of $Inf_{(inf)}$ (h_{max}) and $+/-H_{max}$ are identical, entropy is negative information and vice versa. Only then, can information and random stray information (usually called "white noise") not be discriminated. Under all other circumstances, white noise disturbs the transmission of information. Therefore, information has a second counterpart besides entropy: redundancy. Redundancy is the best means at hand to suppress white noise's negative consequences: unintelligibility. The equivalency of maximum information and maximum entropy has consequences for human communication, since h_{max} is without meaning, as Shannon stated:

"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design. If the number of messages in the set is finite then this number or any monotonic

15 1st order symbols are denotations: they do not require an elaborate interpretation. 2nd order symbols, on the other hand, have connotations, and, therefore, they demand interpretation. Some 1st order symbols are also 2nd order symbols: for example, the ciphers 0–9 (1st order symbols) are equal to numbers (2nd order symbols). According to footnote 14, symbols of the 1st order can be expressed thus:

Term 5: $\sum_{i\to(a-z)}^{n\to\infty} s(1st\_order)$.

That term shall be regarded as equal to the notion "information" in information theory ($\cong Inf_{(inf)}$).

function of this number can be regarded as a measure of the information produced when one message is chosen from the set, all choices being equally likely." (Shannon, 1948, p. 1)

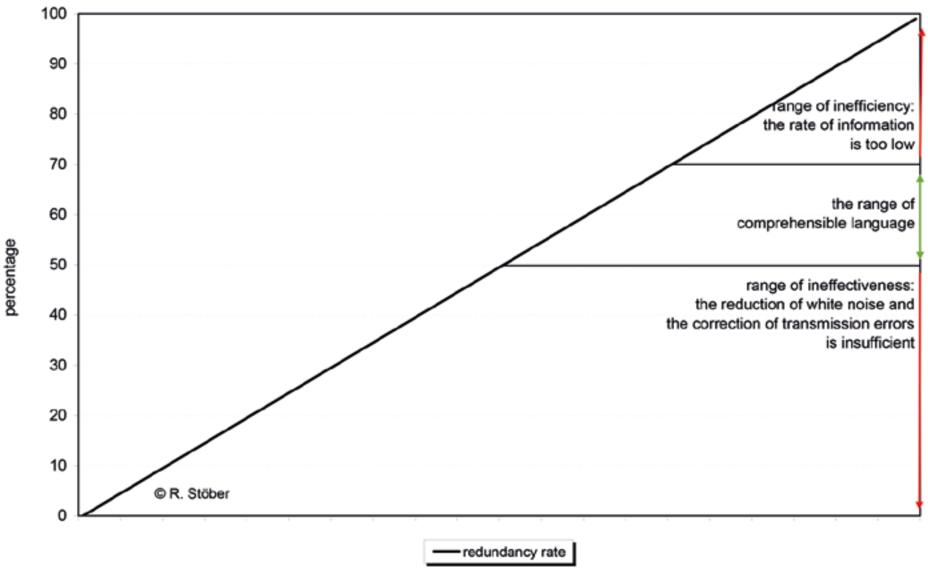
3.5 The second and third layer: Redundancies provide meaningful information

Meaningful information of the 2nd and 3rd order requires redundancies. Shannon stated, "The redundancy of ordinary English, not considering statistical structure over greater distances than about eight letters, is roughly 50%. This means that when we write English half of what we write is determined by the structure of the language and half is chosen freely." (Shannon, 1948, p. 14) In every human language, this is more or less the same. I have calculated different types of texts: journalistic, scientific and poetic articles and books. Furthermore, I have calculated ancient texts in Latin and Greek. Redundancy ranges from 50 to 70%. In general, journalistic and scientific texts have a higher redundancy rate than modern poetic texts. That may be caused by poets striving for greater semantic variation. The ancient texts also showed a similar rate of redundancy. That may indicate that for nearly three thousand years, human language has reached an optimum in redundancies.[16] Some texts (the *Odyssey* and the *Iliad*) show no deviance in redundancy. This is astounding, because research suggests that the two great ballads are not from the quill of the same author. This may be due to the imitation of the style of the older ballad (*Odyssey*, ca. 720 BC) by the younger text (*Iliad*, ca. 670–740 BC). More complex text mining strategies have discovered hidden authorships.[17]

16 I measured the texts in plain ASCII/ANSI code without any mark ups by a word processor. Then the texts were reduced by a ZIP program. The ratio of the original plain texts and their zipped size provides a rough measure of the specific redundancy. The calculated texts (authors; time) are: Iliad [1st – 8th chant] ("Homer"; ca. 670–740 BC): 70%. Odyssey [1st – 8th chant] ("Homer"; ca. 720 BC): 70%. De bello gallico (Caesar; 1st century BC): 63%. A midsummernight's dream (W. Shakespeare; 16th century AD): 58%. Macbeth (W. Shakespeare; 17th century AD): 58%. Faust I and II (J.W. Goethe; 18th and 19th century AD): 49–57%. Stechlin (T. Fontane; 19th century AD): 48–56%. The complete online newspaper *Die Welt*, Dec. 12th 2010: 63%. Some books and papers of mine: 63–65%. The poem "A Rose is a Rose" by Gertrude Stein (20th century) with 99.99 % when enlarged to 1.5 MB is the sole exception. Krippendorf has calculated an average redundancy rate of 70% (Krippendorf, 1986, p. 23).

17 For example, an "Anonymous" in his book *Primary Colors* on the election campaign of Bill Clinton. As later discovered, the book's author is Joe Klein, a *Newsweek* journalist.

Figure 6: The range of efficient redundancy in human language



Despite differences in the details, human language, as such, is rather stable. Conveniently, one can regard Shannon's chains of eight symbols as an equivalent for words in any given natural language. Therefore, we can assume that information theory's 1st order information minus 1st order redundancy approximately equals semantic information ($Inf_{(sem)}$).[18]

What is the explanation for this minimum 50% redundancy? Vowels and consonants alternate in most languages. (Some languages, like ancient Hebrew, do not notate vowels.) The more consonants appear right before a distinct sign, the more the likelihood that the next letter grows to become a vowel, and vice versa.[19] This is the so-called memory function of Markov's chains in languages (Markov, 2006 [1913]). I suggest that redundancy has a function deeply rooted in "reality": redundancy bridges time. This cannot be proven, but under the given premises, when information is regarded as a function of time, it seems to be obvious. I will come back to this.

Until now, we have observed two significant changes in the level of symbol manipulation. As long as 1st level symbols – $Inf_{(inf)}$, letters and numbers – are concerned, it is not necessary to refer to Morris' semiotic triangle. With the first significant change of level, this also transforms: when 2nd level symbols – $Inf_{(sem)}$, words – are concerned, Morris' semiotic triangle becomes crucial (Morris, 1938). The interpretation of the symbol is constituted by signum (sign vehicle), designa-

18 Term 6: semantic information described by information theory
$Inf_{(sem)} \cong Inf_{(inf)} - redundancy_{(1st)}$.

19 This is almost the same with the combination of words (2nd order symbols) in sentences. It is rather likely that the next word is an object, when subject and predicate are already standing there.

tum (object) and interpretant (interpreter). While semantic rules apply to the reference of a sign to its object, syntactic rules refer to the relationship of signs in combination with other signs; and pragmatic rules constitute the relationship between signs, objects and the referent. Morris considered his division as a heuristic division, rather than as three completely separated parts of semiotics. In fact, semiotics concerns the totality of social symbol manipulation. Thus, syntactic and pragmatic rules have to be added to the semantic rules of the wording. The three dimensions of language rules approximately equal a combination of redundancy of the 1st and 2nd orders.[20]

Limited sets of symbols manipulated by limited sets of rules combine to create a huge set of reasonable communications; in theory, the set is infinite.[21] That is the basic benefit of language construction: humans can express what was never thought of before – the "library of Babel".

However, communication is not stable *per se*; one has to repeat it to provide stability of communication. This is both the task and the advantage of redundancies of different orders. Redundancies enable the correction of corrupted communications. Redundancy is the given instrument to strengthen information chains against information loss; it is an effectively implemented feedback loop: redundancy suppresses *white noise*, corrects transmission errors and refreshes forgotten information.

Jumbled letters may illustrate that effect, even though an original Internet statement revealed itself later as a hoax. "Two years ago, a widely circulated statement on the Internet claimed that resarceh at *Cmabrigde Uinervtisy* fuond that sentecnes in whcih lettres weer transpsoed (or jubmled up), as in the setnence you are now raeding, were easy to read and that letter position in words was not important to the ability to read successfully." Nevertheless, a realistic psychological study (Rayner, 2006) confirmed the hoax in parts; especially, transpositions of letters have an effect on reading speed but they do not affect the understanding as such, provided that the fundamental rules of the given language are not violated, and the degree of text corruption does not go to an extreme.[22]

The separate notions of information, regarded as subsets, include one another: Semantic information (words) is a part of information theory's information. Syntactic information (sentences) forms a subset of elements of semantic information. Pragmatic information (texts, messages) provides us with a subset of meaningful information.[23]

20 Term 7: the equivalence of linguistic rules and redundancies
$semantic\text{-}syntactic\text{-}pragmatic\ rules \cong redundancy_{(1st)} + redundancy_{(2nd)}$.
Term 8: pragmatics described by information theory
$Inf_{(prag)} \cong Inf_{(inf)} - (redundancy_{(1st)} + redundancy_{(2nd)})$.

21 In theory, this multitude is smaller than the maximum information – the equivalent of maximum entropy: h_{max}. But that does not really matter when time or space is infinite (cf. Turing, 1936, 1937).

22 When only internal letters were transposed, the reading ability remained pretty high. When starting or ending letters were included in the transposition, the reading ability decreased. Three letter words or shorter ones were not transposed. The spatial gaps between the words were not involved.

23 Term 9: inclusion model of communication into information theory
$Communication \subseteq message = Inf_{(prag)} \subseteq Inf_{(syn)} \subseteq Inf_{(sem)} \subseteq Inf_{(inf)} = h$.

Communication requires at least two meaningful (unidirectional) strings of information (a message): for example, a question and the answer. Therefore, communication is that subset of pragmatic information that establishes a continuity of at least two involved human beings who exchange at least two messages.

News is another subset of $Inf_{(prag)}$. That is probably the most interesting part for communication studies. As Harry Pross (1977) stated, "information is a correlate to ignorance." The 3rd order redundancy is a counterpart to this $Inf_{(news)}$. 3rd order redundancy repeats complete statements. Replicated statements do not provide any news; therefore, human communication might do without them. Repetition, however, confirms the understanding – as every teacher knows very well. Repetition underlines the importance of a statement, it improves the attentiveness of the audience, and it counteracts against information loss. Therefore, human communication is not restricted to new information and it does not omit 3rd order redundancy.[24]

As seen above, the redundancies of different orders diminish from the left to the right side of the term. While 1st order redundancies measure ca. 50% to enable semantic information, the 2nd order redundancy adds approximately 0–20% extra to permit syntactic and pragmatic information. Finally, the 3rd order redundancy does not add any surplus of redundancy in information theory's sense. From the viewpoint of information theory, it does not matter whether or not someone reported a fact before, or whether or not the information was news. It is easy to comprehend why: while the redundancies of the 1st and 2nd orders and the semantic, syntactic and pragmatic information constitute language *per se*, news is different: what news is, the recipient decides; his or her knowledge or ignorance constitutes 3rd order redundancy and information news.

3.6 The layers beyond: Redundancies assume different appearances

Obviously, redundancies appear in different forms. The closer information is scrutinized, the more redundancy – as information's counterpart – depends on the repetition of symbols. The more communication comes into view, the more the repetition of social actions is necessary, too: that means for example, greeting routines, public rituals, private practices, and the habituation of media use. The layers of media (cf. chapter 2) consist of both, the repetition of sets of symbols and repeated action: Writing is (social) action through the use of defined sets of symbols combined by using a given set of rules. Rules, as such, order us to do this or that in a *normal*, i.e., established, way. Press, TV or other *Dissemination Media* use rules, media is institutionalized; this provides, establishes and maintains infrastructure.

24 According to the former terms, it can be stated thus:
Term 10: news described by redundancies
$Inf_{(news)} \cong Inf_{(inf)} - (redundancy_{(1st)} + redundancy_{(2nd)} + redundancy_{(3rd)})$
And integrated in the row of subsets, the next term is a logical consequence:
Term 11: integration of news into layers of information
$Inf_{(news)} \subseteq Communication = Inf_{(prag)} \subseteq Inf_{(syn)} \subseteq Inf_{(sem)} \subseteq Inf_{(inf)} = h.$

Table 4: Forms of redundancy in different contexts

context	*form of redundancy*
information	repetition of symbols
social action	repeated social practices
social structures	institutionalized repetition of practices
communication	combination of a repetition of symbols and social practices
media system	institutionalized combination of repeated symbols, social practices and infrastructures

Examples of repetition and redundancy beyond the information and communication context

The repetition of symbols was discussed in detail above; further examples, therefore, do not have to be given.

Redundancies appear in many forms of *social action*. Every greeting, in the morning, at night, in letters and emails, through the telephone and so on, includes standardized formulas.

Social structures ensure and enhance social action. Structures have to be stable through time, *per se*. Some are institutionalized, such as religion and church or matrimony and family. Others depend on ritualized repetition. Many celebrations, such as weddings, birthdays, Christmas, New Year's Eve, Thanksgiving and many more, include rituals. These may be different from country to country, region to region, religious group to religious group, families to families and so on, but the special ritual as such is an integrated part of any celebration. Some parts of them are stable; they are rather institutionalized. For example, the Christmas celebration is part of an institutionalized social action: the religious practice. Others can vary from time to time.

The *media system* relies on repetition. From the organizations' point of view, every radio or TV station, every film production studio, and every publisher depends on technical and social infrastructures; they have to be built, maintained and, due to necessity, rebuilt; the hardwired infrastructure helps to disseminate the software code (information and communication). The cooptation of the staff guarantees moderate adaptation over time; while some things are going to be new, many old practices endure for a reasonable time. From the content's point of view, every radio or TV format, all film genres and every journalistic format repeats formal aspects, which the recipients and communicators share with one another.

So at last, the interaction between communicator and recipients comes back into view. The beginning of this chapter linked efficiency with interaction. Then the role of redundancies in communication was explained and linked to information theory. The same link – negative entropy – exists with efficiency; so, let us go back in history.

4. Replications: Layers of evolution

4.1 Evolution's job is more than copy and paste

Evolution's job is to copy, modify and paste: DNA transfer is impossible without the replication of information; any change is improbable without a variation of the information. While redundant information provides everything with the necessary stability (from life to culture, especially in media and communication), the question is, what does the drive of evolution depend on?

Seventy years ago, Erwin Schrödinger published one of the most influential books of the 20th century: *What is Life?* (Schrödinger, 1944). He had observed that every life form apparently violates the fundamental laws of thermodynamics.[25] The smaller the violation is, the better life fits into physics. Because life forms reproduce order, they violate the laws. Because all life depends on energy input, the apparent violation is an illusion: Life produces order for itself, but the production of order increases entropy elsewhere; all life forms are open systems, not closed ones; so on the whole, life does not violate the laws of thermodynamics. Schrödinger supposed that organisms feed on "negative entropy" to keep their existence stable. Feeding on negative entropy means workload: looking for food, conversion of nutrition and so on. Therefore, more efficient organisms do not have to "work" as much; through this, they reach an advantage in competition. Furthermore, according to Schrödinger, fitter organisms can handle entropy better as they cope with the intensification of life functions. The metabolism and the reach for resources simultaneously increase. Finally, yet importantly, Schrödinger suggested an information code as the basis of genetics. Thus, he triggered the seminal research of Watson and Crick.[26]

4.2 Evolution's striving for life and culture contradicts entropy

Two factors of change are crucial: One of evolution's driving factors is the search for more efficient solutions; the other factor is the (layer by layer) enhanced reach for resources. The first factor is – casually speaking – energy saving, relatively; from the second follows an absolute increase of energy exploitation. Both factors provide external pressure.

Efficiency is an input-output relationship that is, at its core, determined by the laws of thermodynamics.[27] The pressure of efficiency has a logic: the smaller the

25 The 1st law of thermodynamics, the theorem of the conservation of energy, states that in any closed system, the amount of energy stays the same. The 2nd law of thermodynamics determines a constant rising of entropy in any closed system. The laws were derived from observation; the proof of their validity for every part of our universe is beyond man's reach. Physicists suggest that time may root in the increase of entropy.

26 Modern evolution science still accepts Schrödinger's point of view (cf. Sarasin & Sommer, 2010).

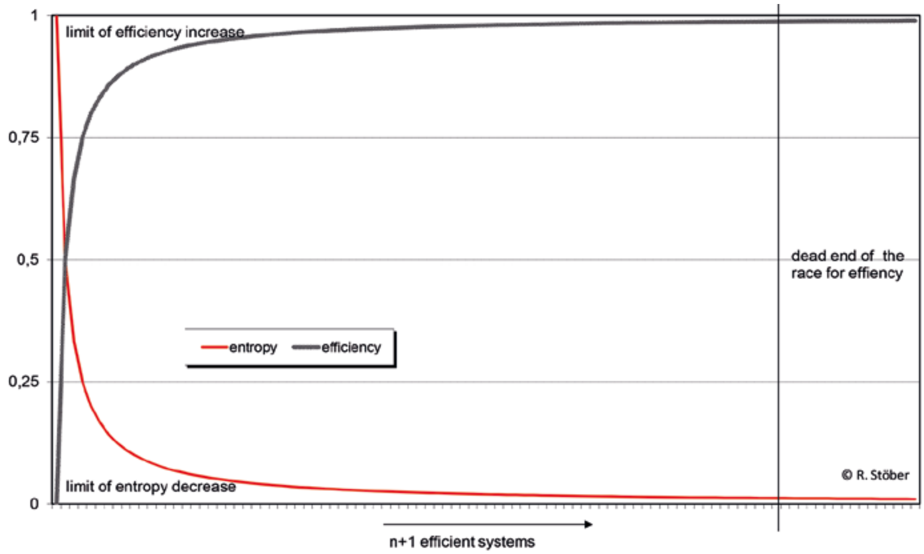
27 For example, for the calculation of the degree of efficiency (ε) of machines or heating systems, one has to measure the power output (p_o) and divide it by the measured power feed (p_f).
Term 12: efficiency calculation by input and output

$$\varepsilon = \frac{|p_o|}{|p_f|}$$

violation of thermodynamics is, the more efficient is the process in question. But the crux of the pressure also lies at hand: no efficiency can expand over its optimum. [28] An increase to the maximum of efficiency is equivalent to a reduction of entropy to its limits, near zero.[29] And therefore, the pressure of efficiency has two consequences: a) as pressure means more pressure in one direction than in the other, it prevents fall backs; and b) as the efficiency race inevitably reaches an end, it will cause – sooner or later – a solution that was not imagined before and that seems very unlikely.

In biological evolution, the pressure does not lay on the structure of the "language" of the genes, for the inner core of the DNA – (and RNA) – code is a multi-redundant strategy of replicating genes. DNA is based on ATGC acids; RNA runs on AUGC. On the one hand, the language of the codes did not alter for many millions of years during evolution. On the other hand, the inscribed information changed; mammals and human beings finally evolved. When the pressure of efficiency does not lie on the code, it has to lie on the epiphenomena: it generates the evolution of life.[30]

Figure 7: The idealized increase of efficiency and decrease of entropy[31]



28 In physics and everywhere else, a *perpetuum mobile* is not possible (cf. footnote 29).

29 While the limit of efficiency (ε) is 100%, the limit of entropy (ΔH) is zero.
Term 13: the limes of efficiency and entropy
$\varepsilon <\cong 1 \parallel \Delta H >\cong 0$

30 Efficiency pressure had already triggered the decisive evolutionary step toward eukaryotic micro-organisms (Martin, Lane, & Schmitt 2013). Efficiency pressure from climatic factors appears to have influenced the evolution of human language sound systems (Everett, Blasi, & Roberts 2015).

31 The figure can be written as
Term 14: idealized increase of efficiency and decrease of entropy

$$\Delta H = \frac{1}{n+1} = 1 - \varepsilon \parallel \varepsilon = 1 - \frac{1}{n+1}$$

And when the efficiency race – sooner or later, but inevitably – comes to an end, the competition has to switch to a new field of competitiveness; otherwise, evolution would stop. That switch at the limit of efficiency is an effectiveness switch; it enhances the reach for resources. While the increase of efficiency slows down the progression of entropy, the enhancement in the reach for resources leads to the contrary; so the evolutionary process finally accelerates the growth of entropy. Rephrasing that: when life is order from disorder, the paradox consequence is the opposite – growing disorder. Another consequence is even more important, especially for my reasoning: evolution adds one layer after the other.

To sketch out the range of the analysis from energy related topics to information processing: the evolutionary process – with its double striving for efficiency – adds more and more complexity to life, environment and – finally – culture. The increase in the reach for resources dramatically expanded from mono-cell organisms to multi-cell organisms to – at last – intelligent life forms. This caused advantages and disadvantages at the same time: while animals in general are much worse energy converters than plants, most animals are mobile and have a brain, too; so biological information processing enables mobility and, thus, expands the reach for resources and compensates for a less efficient biological layout.[32] However, an important question is whether or not the alternation of expanding the reach and diminishing entropy is relevant for human culture. Does it have effects on cultural evolution?

To explain the paradox of theses interdependencies, let us look at an efficiency driven cultural process that is beyond doubt: In economics, the conversion of energy, efficiency, work and workload in services and money is apparent. Therefore, the efficiency scheme is applicable to any system or subsystem that runs with work, labor or services. In the next table, the left hand column and the right hand column refer to "generalized media" (cf. Parsons, 1963).

Table 5: Conversion of efficiency

dimension	*connection*	*measure*	*further possibilities of conversion*
work	= force * distance	joule, calories	work *with* money
power	= work/time	watt, hp/h, etc.	services *with* money * time

The importance of energy conversion in the given system – from rather big portions to just small degrees – constitutes the "weight" of the efficiency claim for this system. All systems that are close to physical energy consumption, depend highly on efficiency: such as machines. Every system that is related to the economy depends on efficiency competition a little bit less: for example the media. Any system that is far from physical energy consumption or economic arguments depends rather less on striving for efficiency: fine arts and others. However, as the examples given below indicate, even systems far from physics and economy can be forced into efficiency competition; they may have to accept a higher degree of "economization" forced on them by the outside.

32 See on the causality of mobility for intelligence (Thier, 2014), and on the necessity of simultaneous (redundant) fire of neurons (Engel, 2015).

Every system or subsystem is subsumed to efficiency competition, when work, labor or services is at hand; they convert into one another. The conversion of labor, goods and services, in parts or as a whole, is really old and one of the earliest impetuses of trade. In 1776, Adam Smith had already explained the principle of the division of labor by the "propensity to truck, barter, and exchange one thing for another" (Smith 1776, p. 17 [chapter I, 2]). More abstractly speaking, in any given social and cultural system, the "generalized media" of exchange convert work and power into services, time and money and vice versa.

Examples of efficiency in equivalent systems and subsystems

Many systems seem to be unaffected by efficiency claims. Nevertheless, all of them include elements of it. Three systems that do not seem to fit into the efficiency scheme (at first sight) will be scrutinized: the systems of higher education, fine arts and politics. Contrary to first impressions, they are subordinated to efficiency driven competition, because they are connected with intermediating "currencies"; the currencies are qualia of efficiency.

The first example, higher education: Today's economization of education may be wrong, but the ethical standpoint is here irrelevant. We can observe many recent trends of economization in our universities. The system of universities may serve as a subsystem of the system "higher education"; another subsystem on this level is "elementary education." Any particular university may serve as a subsystem of the whole university system. Any especial university contains subsystems, such as professors, departments and faculties. As a casual joke goes, there is no quarrel in universities – except for rooms, staff and money. From my point of view, it is dubious that declarations of centers of excellence and the measurement of scientific output contribute to an improvement of science and higher education in the end. Nevertheless, as long as some members of the scientific community submit themselves to external rules of competition, all members are forced to do the same. A) This, necessarily, leads to a leaner and more mainstream issues oriented science; we observe this in our own subject. Recent developments, thus, may lead to a more efficient educational system; that is, however, only true from the external reference point of a society that does not appreciate research and teaching on subjects with, at first sight, no clearly defined benefit. B) Mainstream science may be both advantageous at the moment and becoming fatal in hindsight. This time driven paradox may be doubly true, for the subject itself and for the society as a whole. Therefore, more efficiency does not lead, necessarily, to a better world and progress in general. Thomas S. Kuhn, however, reasoned long ago, that the petrifaction of mainstream science, sooner or later, will lead to a paradigm shift (Kuhn, 1962).[33]

33 A scientific revolution, as described by Kuhn, has many similarities with the emergence of new media described here. The progress in established sciences slows down, so do their efficiency gains. This may be worthy of further reasoning – just not here.

The calculus for the fine arts is much alike. At the beginning, let us divide the cultural field of fine arts into artisans and appreciating individuals. The "work" of the artisans provides society or its individual members with art that cannot be created by the other members of society. Art always has its price; it is appreciated for its qualities in entertainment, diversion, enlightenment, and for other reasons. The price may be money, it may be reputation or attention. The higher the reputation of the artisan rises, the more the "price" for art increases. Then, possibly, legal or illegal reprints, copies and imitations in any form will emerge. So by and by, more and more players in the field of fine arts are going to interact. A) As long as all consumers of arts have to pay for it, they have to work for the cultural expenditures. Every creative activity, at least in some of its parts, is work, too. With "work" as such, the efficiency argument becomes applicable. B) As long as both the production and the reception of art use cognitive capacities, art is strenuous. And, most likely, quite a large number of recipients prefers a special piece of music or that piece of fine arts, which promises easy listening or "easy looking at," when the only goal is entertainment.

In politics, many subsystems seem reasonable: here, political parties may serve as convenient subsystems; they compete for voters and political power; the party with the most effective campaigning wins elections and power.

The notions "system" and "subsystem," meant here, are not as hermetic as in normal "system theories." The notions, nevertheless, share with system theories a subordination to the same kind of rules. The most important element to use to subdue any system and its subsystems to an efficiency competition is the question, whether or not an intermediating currency (or "generalized media") exists. It may be work that is necessary, money that has to be paid, or time that has to be given. In general, almost everything fits into an efficiency calculation.

Additionally it is said to any critic of the relevance of the examples given above: They are not as far from the subject of this article as it seems, for every system can serve as a proxy for media content; the system of higher education serves as a proxy for information and knowledge; fine arts illustrates emotions and entertainment; politics stands for opinions and orientation.

4.3 Game changing effectiveness

The reach for resources has expanded more and more: from the primitive people at the dawn of men to the high cultures in ancient times to the modern technical civilization in the present. The most astounding pivotal turn in history happened at the dawn of humanity. It is almost undisputed now that the development of intellectual capacities and language were parallel.[34] That scheme has been under-

34 Tomasello (2014) and other modern scholars suggest that language enabled cooperation; social cooperation led to specialization; specialization is equal with a self-restriction to that task that the specialist can do the best: one is hunting, one is cooking; another one is looking after the youngest or the oldest members of the tribe, and so on. Adam Smith had already laid stress on the "difference of natural talents in different men" (Smith, 1776, p. 20 [chapter I, 2]).

lying history from the very beginning of human social life up to the latest trends of differentiation in modern societies. Every time a new reference point (for the competition in efficiency) began, the effective reach (for resources) was also enhanced; consequently, every step became game changing. That is, the functional surplus means more than the sum of its parts; the super-additive function supplies new, unexpected and useful properties; innovation is emergent.

All the quantum leaps concerned two different dimensions: energy consumption and information processing. At the present, this is most apparent: today's energy consuming engines have become more and more efficient; at the same time, oil exploitation is expanding rapidly due to fracking; environmental sustainability does not count at the moment; the civilization expands its reach on energy and informational resources *and* is getting more and more efficient at the same time. The same is true with information processing: every computer generation is more efficient than the older, but the demand for information processing has exploded in the meantime; so, the total energy consumption for digital purposes far exceeds the past; the server plants of Google or Facebook are efficient, but they need power plants for themselves (cf. Brynjolfsson & McAfee, 2014, p. 140).

Only revolutionary solutions will become game changers. After every point of change, the new system may be less efficient. However, it is much more effective. A decrease in efficiency does not matter, as long as the new solution adds a functional surplus; as long as the solution compensates inefficiency with a wider reach for input, the negative aspects do not count. A game changing point does not necessarily establish more efficiency *per se*. That is evident: Locomotives, for example, do their work more effectively than horses or stagecoaches. They can carry more people and more goods at a wider range, without getting tired and so on. Concerning energy consumption, they did not have to be more efficient; the first locomotives were immense energy consumers. Nevertheless, they changed transportation dramatically. They did not feed on hay and oats as horses do, they "fed" on stone coal – and later on petrol and electricity (provided by nuclear, gas, wind power or other power plants). With these energy sources, the new railway transport system had a much vaster energy supply at hand than the old transport system based on horses and stagecoaches.

The example shows this: More of the same may provide solutions for old problems; it cannot solve new problems; and it never anticipates the solution of a problem yet undiscovered. A famous quote[35] can illustrate that: Josef A. Schumpeter once declared; "Add successively as many mail coaches as you please, you will never get a railway thereby" (Schumpeter, 1961, p. 64). Obviously, this reasoning is more closely related to efficient machinery than to culture; even so, the explanation of economic evolution, Schumpeter hinted at, is cultural change, too.

35 Luckily, it refers to the older understanding of communication (cf. chapter 3.2).

More examples similar to the stagecoach analogy
Aircrafts and airlines, one may combine as many horses or locomotives as you like, you will never fly. “No train can run on thin air” (Pratchett, 2013, p. 179). One may combine the “Deutsche Bahn” with the former “British Rail” and the French “Société nationale des chemins de fer français” (SNCF); the combination does not make up an airline. (Therefore, they ought to concentrate on the relevant: being on schedule.)

One can add as many printing presses as one likes; the addition does not lead to newspapers; it just provides more copies. The main difference between printed copies (for example, of a book manuscript or a leaflet) and a newspaper lies within a singular dissemination of information *versus* a continuous stream of “news.”

Add as many telegraph lines as you want; no Internet emerges. Because communication by telegraph is centralized, whereas communication by Internet is not. The telegraph’s communication is time-bound; Internet communication, necessarily, is not.

One may buy many vaudeville theaters and engage a bunch of slapstick comedians; that does not lead to cinema and slapstick comedies á la Chaplin or Buster Keaton.

Many wireless devices will not sum up to a broadcasting system, because citizens’ band radio (CB) uses the mode one-to-one and radio is one-to-many.

A Million abacuses do not provide a mainframe computer; 100 000 disconnected mainframes are no Internet; one billion emails are not a social network.

Every cultural game changing point adds options.[36] Society gets more choices: people can travel by walking or by stagecoach or by railroad or by airlines; they can write letters or they can use email; they can read the press or listen to radio or watch TV; they can communicate in traditional ways or via social media. After a point of change, they can use both, the older or the newer cultural technique.

Nevertheless, the surplus in opportunities is not positive in every way and for everyone. On behalf of normal people: some people may cling emotionally to older cultural techniques but feel forced onto the innovation by the majority; others may use the new technique but, nevertheless, complain about cultural impoverishment. On behalf of producers and the economy: every new cultural technique means that old economic goods will go out of fashion, they cannot be sold any more; or that only some products and producers will survive in a niche. The evaluation of the options’ worthiness is a matter of view. Sometimes, there are winners and losers; sometimes there are mainly winners, sometimes mainly losers. That is quite a paradox.

36 The reading of a clever, but polemic book has sharpened my perception of enhanced options that is caused by evolution’s tinkering (Taleb, 2014). The author has won a good deal of publicity for being one of the few who saw the signs on the wall before the world economic crisis of 2008. Besides its polemics – mainly against academic economics – the book offers an elaborate reasoning on the robustness of economy, society and culture.

4.4 The paradoxes of zero-sum games and win-win situations

Economics hardly dispute the maximization of efficiency; economic efficiency is a question of competition. Competition takes place in “relevant markets.” Relevant markets are constituted by traded goods that can be substituted with equivalent goods. For example, information media compete with information media; entertainment media compete with other entertainment media. That is a functional perspective. The formal perspective is: national newspapers compete with other national papers (of the same country), street magazines with zines; a radio station for rock music competes with other stations of the same format. And so on. Relevant markets can be defined the more precise, the more homogenous their goods are. The homogeneity may be defined from supply’s side or from demand’s side.

Thus, we can cut the efficiency of media markets (ε_{mkt}) as a whole into two (idealized) halves: the communicator’s media supply (*cms*) and the recipient’s media demand (*rmd*), which may serve as a *pars pro toto* for general considerations on a paradox called “Schumpeter’s creative destruction.”[37] Everyone may replace the notion ε_{mkt} (efficiency of the media market) with all other convenient systems. One just has to make sure that the chosen system fits more or less into an efficiency competition. This is also true of subsystems: subsystems (*subsys*) may substitute the given examples *cms* and *rmd*, if they fit into the greater system. Whether or not systems and subsystems fit into the striving for efficiency is a question of conversion; this will be discussed below. This calculus is regardless of the “men in the middle”; therefore, its idealized calculation is much more complex in reality.[38]

37 Therefore, 2 may divide the efficiency of any market, when its efficiency is projected for 50% on *cms* and for the other 50% on *rmd*. With supposed equal shares in efficiency for the communicator’s media supply (*cms*) and the recipient’s media demand (*rmd*), the term is thus:
Term 15: efficiency of the “creative destruction”

$$\varepsilon_{Mkt} = \left\{ \left[\left(1 - \frac{1}{n+1}\right) \to cms \right] \div 2 + \left[\left(1 - \frac{1}{n+1}\right) \to rmd \right] \div 2 \right\}$$

38 In the case of more than two subsystems, the divisor has to be higher than 2. The more subsystems come into view, the more complicated the calculus will get. For more than one subsystem, but with the assumption of equal shares, the term can be modified thus:
Variations of Term 15, with three subsystems (Term 15, A):

$$\varepsilon_{Mkt} = \left\{ \left[\left(1 - \frac{1}{n+1}\right) \to subsys_1 \right] \div 3 + \left[\left(1 - \frac{1}{n+1}\right) \to subsys_2 \right] \div 3 + \left[\left(1 - \frac{1}{n+1}\right) \to subsys_3 \right] \div 3 \right\}$$

and with n subsystems (Term 15, B):

$$\varepsilon_{Mkt} = \left\{ \left[\left(1 - \frac{1}{n+1}\right) \to subsys_1 \right] \div n + \ldots + \left[\left(1 - \frac{1}{n+1}\right) \to subsys_n \right] \div n \right\}$$

Note that this is an idealized assumption of equal shares and losses. One might suppose that *n* subsystems have to share the profits of efficiency’s increase equally, too. However, an equal share of the efficiency increase is not necessary. The gain for one subsystem may be much higher than the loss of any other subsystem:
or (Term 15, C):

$$\varepsilon_{Mkt} = \frac{\sum_{n \to \infty}^{n} \left(1 - \frac{1}{n+1}\right) \to subsys_n}{n}$$

The rationalization of efficiency gains may sometimes seem opaque. One thing, however, is for sure: The efficiency of the whole system (market, sphere of competition or whatsoever) cannot surpass 100%. An individual person or one organization or one subsystem gets a payback of more money, work, service, time or other investments. However, it depends on the other players and their specific input; the spread of their gains can vary. Even so, from the perspective of efficiency distribution, this finally leads to a zero-sum game.[39]

The calculus of efficiency becomes the more complex, the more subsystems (as *cms*, *rmd* and so on) and the more different points of reference get involved. This is not trivial: on the one hand, the efficiency projections of subsystems have to contribute to the efficiency of the whole system; on the other, they do not have to be identical with the efficiency of the whole system or the efficiency of the opposing subsystem. To provide an example for that distinction: the efficiency of the whole *communication system* may be a “news related efficiency.” Then, the input-output calculation for “newsgathering, news processing and news dissemination” constitutes the efficiency of the *communicator media subsystem*. Accordingly, the efficiency of the *recipient media demand subsystem* is constituted from efficiency in “news reception and alternative costs for media demand.” So, *cms* and *rmd* use different benchmarks for the evaluation of efficiency.[40]

There are two different changes in efficiency: efficiency changes in the system as a whole, and the development of efficiency shares, projected for each subsystem, at any given point of time. The system as a whole, from one point of time to another point of time, gains more and more efficiency with every improvement, until, hypothetically, it reaches 1. The efficiency gains, however, do not have to be shared equally (cf. Brynjolfsson & McAfee, 2014, pp. 102–117). Furthermore and *in theory*, the difference of efficiency attributions over all subsystems is 0 – at

39 With two subsystems, in our idealized assumption of reciprocal efficiency share of communicators and recipients, the abridged version of Term 15 is:
Term 16: zero-sum game of the paradox “creative destruction”

$$0=\varepsilon_{Mkt}-\left\{\left[\left(1-\frac{1}{n+1}\right)\rightarrow cms\right]+\left[\left(1-\frac{1}{n+1}\right)\rightarrow rmd\right]\right\}$$

40 For each part, the first expression of Term 16 – in brackets *(1-1/(n+1))* – relates to the whole system. The projection indicates the share in the efficiency changes of any subsystem compared with the system as a whole. More accurately written, it is this (Term 16, A):

$$0=\varepsilon_{Mkt}-\left\{\left[\left(1-\frac{1}{n+1}\right)\div 2\rightarrow cms\right]+\left[\left(1-\frac{1}{n+1}\right)\div 2\rightarrow rmd\right]\right\}$$

or (Term 16, B):

$$0=\varepsilon_{Mkt}-\frac{\varepsilon_{cms}+\varepsilon_{rmd}}{2}.$$

According to the argument above, Term 14 has to be transformed for more than two subsystems. Even considering different reference points of efficiency, neither the efficiency of any given system nor the efficiency of any of its subsystems can surpass the limit of 100%. And the increase in efficiency does not have to be shared equally. For, from Term 15, C derives (Term 16, C):

$$0=\varepsilon_{Mkt}-\frac{\sum_{n\to\infty}^{n}\left(1-\frac{1}{n+1}\right)\rightarrow subsys_{n}}{n}.$$

any point of time with a given efficiency. *In practice*, this seems to contradict the assumed permanence of change. The contradiction, however, easily solves near the dead end of every efficiency race.[41]

Economists do not get tired of declaring economics as a win-win situation. With the argument given above, it is possible to combine the win-win suggestion with the zero-sum game of efficiency: The win-win situation arises from a side effect of the efficiency race, an enhanced reach for resources. While the dead end race for more efficient solutions is quite deterministic, the enhanced reach for resources is not – and will never be – because it depends on emerging innovations. While the zero-sum game at the dead end race for efficiency results from (smaller and smaller) improvements, the enhanced reach for resources derives from (great) innovations. Innovations enormously improve the effectiveness of every social system, not just of media and communication systems.

Innovation theory literature labels the dramatic changes "basic innovations"; they are distinct from the smaller "innovation improvements" (i.e., after a basic innovation, a new race for more efficient solutions will start with small improvements). Every basic innovation establishes a new field of competition. The knack of Schumpeter's "creative destruction" lies within this combination of dead end efficiency races and exponential reach for resources; or more abstractly speaking: the paradox is a genuine combination of zero-sum games with win-win situations.

Schumpeter's paradox suggests "creative destruction" in the circumstance of a ripe market. Markets get ripe when efficiency reaches its dead end race (cf. figure 7); and that precedes major innovations. While in some ripe fields of competition, too many participants reduce the chance for profits, in other ripe markets a monopoly with huge profits for one player and none for all the others may exist. Both extreme situations lead to the same place: innovation at the dead end of the race becomes a question of necessity for many players – which is not seen by all. Especially, the most successful players are often doomed to miss revolutionary new chances; they seem to be blindfolded by the prospect of a deterministic efficiency race; the misperception results from the strategy "never quit a running business"; the conservative strategy of preserving the latest success is the main obstacle of new ideas in established firms (cf. Wu, 2010, p. 34, 122, 208). Their passivity allows room for the ideas of newcomers; these create opportunities that the society will take as options.

41 Expressed formally, the Delta of efficiency (the difference of the system's efficiency compared to the efficiency sum of the subsystems) at any point of time is 0 (Term 16, D):

$$0 = \Delta\varepsilon \rightarrow subsys_n \,,$$

While the maximum delta of efficiency gains – over the whole period of improvements (from the basic innovation to the dead end race of efficiency) – might finally reach 1; the efficiency in figure 7 can be written as (Term 14, B):

$$1 = \delta\varepsilon \rightarrow sys \,.$$

Examples of zero-sum games of efficiency and win-win situations in effectiveness

Higher education (professors, departments and faculties in any especial university) competes for resources, so every university competes with others: for students, scholars, reputation and excellence and, last but not least, for money. It is the same with the interrelations of higher education (universities) and elementary education (schools): With a fixed budget, money for the universities cannot be given to the elementary schools.

In any given situation with fixed resources, the competition is a zero-sum game: A) when the number of students stays stable from year to year, some competing universities gain, while others lose. When politics force the universities as a whole to intensify the competition, the outcome is the same. Every university that attracts more students for the same amount of advertising activities is more efficient than others; but, obviously, the reach for resources may have increased; for example, if the percentage of each age group of high school pupils admitted to universities increases. B) When the number of journals of any particular science is fixed, all scholars in this field compete for the same printing space. This is a zero-sum game, in which those scholars who established the best (= most efficient) publishing strategies win. A win-win situation may arise from effective cooperation, for example, when competing scientists initiate a new publishing platform, perhaps an open access online journal.

The calculus for the fine arts is much like this. Art always has its price, when appreciated for qualities in entertainment, diversion, enlightenment or for other reasons: it may be money, it may be reputation. The higher the reputation of any artisan rises, the more the "price" for his or her art increases. At last, the art's prices get so expensive, that only museums and millionaires can afford it. For the artisan, as long as he or she is not deceased, this is a gain; for the normal public, it is a loss. A) One possible limit, here, is the total art expenditures a society can afford. Once more, this might be by "work," time or money: of the society as a whole, of the artisans or of the individuals. If the expenditures increase further, necessarily, that has to happen at the cost of other subsystems of society (sports, transportation system, beverages and meals, living quality in general or any other). B) Art provide effectiveness to every society by improving the quality of private, public and social life.

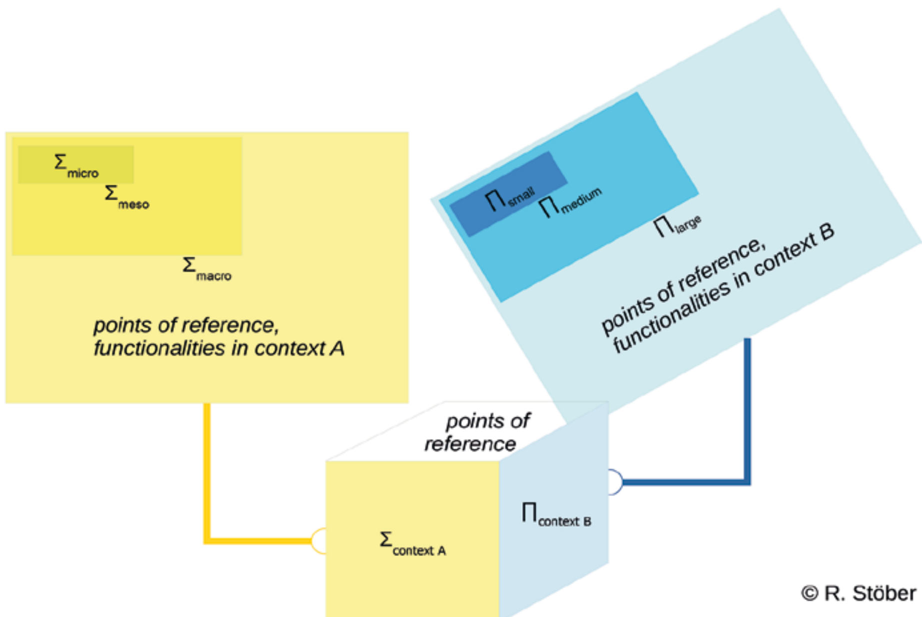
In politics, the limit is a 100% share of votes. A) Any vote for one party is lost for the others. B) Win-win situations may result, after elections, from clever coalition strategies. Win-win situations may also result, before election day, from an expansion of the electorate. The increased reach for voters – by a reduction of voting age, by admission of immigrants (for example, at local elections) or by other means – however, is a win-win situation in absolute votes; it remains, from the point of view of power, a zero-sum game. Its win-win effectiveness may derive from a prudent attribution of power, so that the outcome of politics provides liberty, peace and welfare for all. Maybe, the controversial "nudging," the psychological manipulation of citizens to do the right thing, is one method to create a win-win situation for all by small means.

The "players" may be individuals, firms, organizations or the whole society. The projection of efficiency ranges from machines to total systems. The contexts of time and space may be short and small *or* long term and global. The smaller the chosen contexts are, the easier a calculation may appear. The bigger the contexts chosen, the more complex the calculation will become. Nevertheless, even an "easy" calculus is not trivial, because every point of reference (cf. next table) is just a single factor of the whole calculus; combined, they appear as an aggregate, as a partial sum or as a product of the points of reference. Furthermore, every analysis has to integrate the aggregated points of reference with the conversion of efficiency (cf. table 5).

Table 6: Points of reference for efficiency and functionality

context A	*micro*	*meso*	*macro*
For whom?	individuals (men, creatures)	family, tribe, organization	society, nation
For what?	machines, single media (newspaper, radio station . . .)	parts of technical infrastructure, media organization	whole technical infrastructure, media system
context B	*small*	*medium*	*large*
What time?	short term	medium term	long term
What place?	small spaces	wide areas	global

Figure 8: The sum of reference points of functionality in context dimensions A combined with
the product of reference points of functionality in context dimensions B



While *context A* integrates by summing the different parts (meso by micro; macro by meso), *context B* serves as a divisor or multiplicator: as shown in table 5, *work* results from *force* multiplied with *distance*, and *power* equals the division of *work* through *time*. Both context dimensions may be integrated from micro to macro – and accordingly, from small to large. Therefore, while work is the driving force of the calculus, some generalized *media of change* are help tools of conversion: that is, in the modern, economized world, mainly money; with time it is similar, "time is money" is proverbial. Furthermore, any time gain is an indirect gain of efficiency or effectiveness, for two reasons; the first I indirectly explained above. Because time is the divisor of every efficiency calculus, any work that can be done in a shorter time means the application of a bigger force. The second gain results from *opportunity costs*.[42] The range of money or time sparing mechanisms is wide:

Table 7: Money saving and time sparing effects of efficiency gains through media use

media use of . . .	*money saving effects*	*time sparing effects*
integration into pictograms (from street signs to emoticons)	indirectly (by time sparing effects)	arousal of immediate attention and understanding
deconstruction of symbols (from replication of standardized types to digitalization)	indirectly (by time sparing effects)	development of a universal/ multi-purpose transmission code
infrastructure in general (postal, telegraphy, radio, TV, Internet, even streets, railroads and other grids)	none at the beginning because of huge investments at the start; money saving effects accumulate over time due to time sparing effects	from the beginning (faster travel, faster information transport, faster and more reliable media and communication dissemination)

Apparently, from the starting point of a most simple rule (the zero limit of entropy or 100% limit of efficiency), an utmost complex situation has derived. The efficiency race has led, by orthogonal switches, into many fields of competition.[43] In every new field of competition, effectiveness reaches a new level. The levels are constituents of the different layers; the example of media layers gave an explanation. Figure 8 and figure 9 illustrate both the complicated evolution of different layers and the complexity of the calculus of efficiency and effectiveness: while figure 8 illustrates table 6 and table 7, figure 9 combines the natural limits of efficiency with (as a matter of principle) the limitlessness of effective reach. The limitlessness of the effective reach is caused by basic innovations; the limits of efficiency gains are due to the *quasi-natural* limits of innovation improvements.

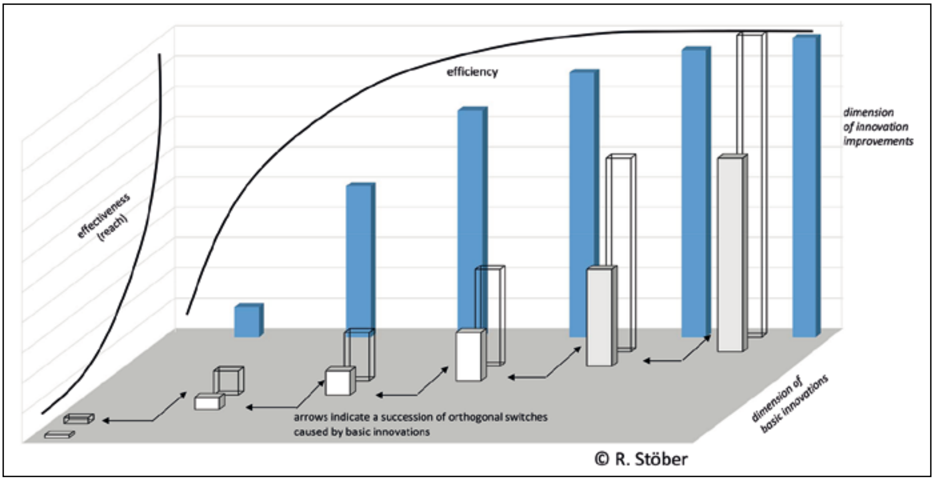
42 The notion "opportunity costs" usually applies to work done instead of another job or profits that result of time sparing mechanisms.

43 The innovation improvements of media – in $X_1, X_2, \ldots X_n$: for example writing, vaudeville entertainment, arithmetic and others – can be described formally thus:
Term 17: jump fix efficiency races and their orthogonal switch to other fields of competition

$$\left\{\varepsilon_{X_1},\ \varepsilon'_{X_2}, \ldots \varepsilon''_{X_n}\right\} = \left\{\left[\left(1-\frac{1}{n+1}\right) \rightarrow x_1\right], \left[\left(1-\frac{1}{n+1}\right) \rightarrow x_2\right], \ldots \left[\left(1-\frac{1}{n+1}\right) \rightarrow x_n\right]\right\}$$

Note that the blue columns (the limited efficiency) have to be applied to each basic innovation; they ought to be repeated six times on the z-axis:

Figure 9: Efficiency and effectiveness



The examples of media evolution combine both: the dead end efficiency race and the enhanced effective reach. The momentum of planning always hinted at the improvements of *old media*. The innovation improvements of media: for example writing, vaudeville entertainment, and arithmetic aimed at an increase of efficiency. When the orthogonal switch happens, society realizes: The printing of books enables the periodical press. Vaudeville amusements are transformed into storytelling motion pictures. Arithmetic sidekicks become mighty symbol manipulators. Thus, the orthogonal switch initializes a transformation. The result of each point of change is an increase in the effective reach of information, media and communication. Every dramatic increase pushed humanity onto a new level. There have been some more emergent basic innovations throughout the cultural history of humankind: for example, the game changers of the Neolithic revolution or urbanization or industrialization. But the changes in information, communication and media were not the least important.

Admittedly, this seems somewhat abstract. To test the concept, let us make some calculations on the game changing points of media evolution.

4.5 Some calculations on pivotal points of media evolution

A first example: Gutenberg was neither the first printer nor was he acting beyond the economic and cultural traditions of his time. When he invented printing with removable types, he invented an instrument just for metal molding. Everything else was in use before: the alphabet, the press for wine production, printing with woodcuts, production of paper and so on.

While the printing of his bible was in progress, he and his financier, Johann Fust, disengaged. Fust started a lawsuit against Gutenberg – he wanted more money back. Because of this litigation, many details about the costs of the first printed bible are known. Thus, Gutenberg's bible and the trial Fust vs. Gutenberg provide data for a hypothetical calculation. The example compares the printing costs with an alternative calculation for writing costs. Gutenberg printed approximately 180 copies of the famous 42-line bible. About 35 were printed on parchment; the others were done on paper. If writers had done his "work of books," 180 writers would have had to work hard and precisely for three years. Writers' skills included foreign language capabilities – for example, in Latin and Greek. So they earned well: 30 to 35 florin (fl.) a year; typesetters received wages half as high.[44]

Gutenberg's staff consisted of 17 men and women of different qualifications: cooks, waiters, printers, typesetters and correctors. They fulfilled the task in 13.5 months at least. So, the cumulative costs for wages would have differed widely. The same would have been true for the costs of beverages, food and lodging. The printing material, on the other hand, would have been rather unaffected. Printing as well as writing afforded the same amount of paper with respect to parchment; with ink for both purposes, it was the same. On the other hand, the gross return on investment – that is the cumulative price for 180 copies, without a margin for retailers – differed widely, too: a luxurious handwritten bible at Gutenberg's time was five times more expensive than a printed copy; a handwritten parchment version was sold for 500 florin, the printed version was sold for 100 fl. A paper copy was half as expensive, approximately. Roughly calculated, the profit ratio was three times higher in the printing business than with a large scriptorium.

Table 8: Alternative calculation for Gutenberg's bible (in florin)

	written bibles	*printed bibles*
nutrition	9 600	340
materials (paper, parchment, ink)	1 140	1 140
wages	14 724	232
lodging (heating, lighting, rents)	3 529	125
total investment	*28 993*	*1 837*
gross return on investment	52 500	10 500
profit	**23 507**	**8 663**
in percent	81%	472%

What does that mean for effectiveness and efficiency? The effectiveness calculus is an easy one: the writing staff would have been approximately ten times larger than the printing staff. Nevertheless, the printing was finished in (a little more than) one third of the time. That is, printing was thirty times more effective than writing from the beginning.

44 For the data used here, see Hoffmann (1993) and Stöber (2014a).

However, what about efficiency? It is appropriate to take a look at the *communicator media subsystem* and the *recipient media demand subsystem*. For Gutenberg and printers of his like (*cms*-side), the calculation is this: the efficiency gains equal the money saving effects (caused by the process of production) plus Gutenberg's gross return on investment. The purchasers' efficiency gains (*rmd*-side) equal the gross return on investment of all handwritten copies minus the gross return of investment of all printed copies.

Table 9: Efficiency gains for Gutenberg and the purchasers of his bible

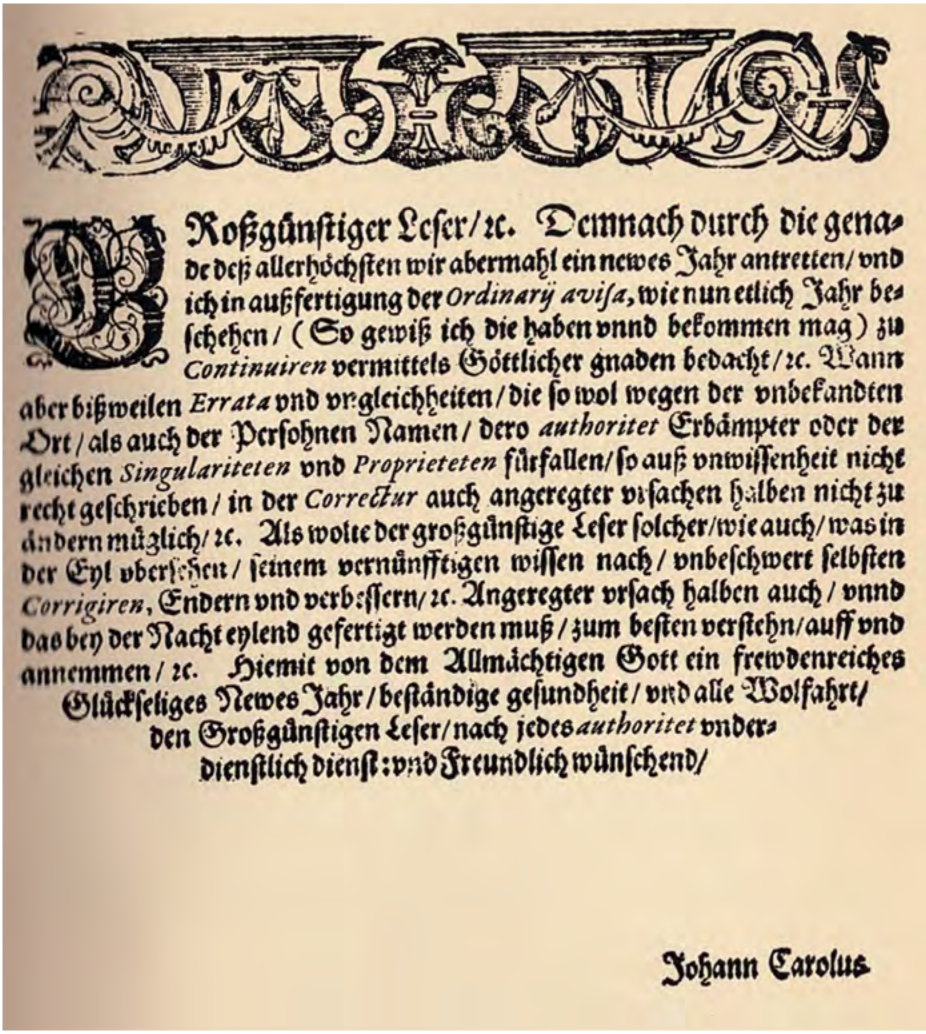
	efficiency gain (florin)	*share in efficiency gain (percentage)*
for *cms*	37 656	47.3
for *rmd*	42 000	52.7
total	79 656	

It is apparent that, more or less, both sides take a 50% share of the efficiency gains. The question is, why? In theory, Gutenberg might have enlarged his profits by selling the bibles at higher prices. That would have increased his advantage at the cost of the buyers. It is very speculative, but he might have wanted to avoid the risk of selling nothing – or just a few copies. Even when the economic concept of the "price elasticity of demand" had not yet been discovered, Gutenberg might have a feeling for the relationship of product prices and the chance to sell them.

A second example: Let us look at the media switch from handwritten newspapers to printed newspaper copies. As far as we know, Johann Carolus invented the printed newspaper; he was a printer and bookseller in the early 17th century and lived in the German imperial city of Straßburg, which is Strasbourg in France today. My next calculations are indebted to Martin Welke's lifelong research on Carolus and the first newspaper (cf. Welke, 2008).

In 1605, Carolus asked for permission to have a newspaper monopoly. He explained his business in a request directed at the imperial city's council: He had bought a printing office and a bookshop, so he was obliged to repay huge debts and interest rates; beside his bookshop business, he had sold handwritten newspaper copies to "several" gentlemen. But the copying went on too slowly for him; so he had printed the newspaper "recently" (for 12 weeks before the date of his request). Now he wanted to improve his business model; furthermore, he wanted to exclude other printers from the same business; therefore, he asked for the license of a ten year monopoly in newspapers. The council denied his request "bluntly." Nevertheless, the members of the council did not forbid him to print a newspaper as such. Therefore, Carolus continued his newspaper business; he just did it without the protection of a granted monopoly. A first copy of his newspaper has survived since 1609. Its New Year's foreword explains some circumstances of early modern times' newspaper production.

Figure 10: The foreword of Carolus' newspaper (1609)


GRoßgünſtiger Leſer/ ꝛc. Demnach durch die gena-
de deß allerhöchſten wir abermahl ein newes Jahr antretten/ vnd
ich in außfertigung der *Ordinarÿ aviſa*, wie nun etlich Jahr be-
ſchehen/ (So gewiß ich die haben vnnd bekommen mag) zu
Continuiren vermittels Göttlicher gnaden bedacht/ ꝛc. Wann
aber bißweilen *Errata* vnd vngleichheiten/ die ſo wol wegen der vnbekandten
Ort/ als auch der Perſohnen Namen/ dero *authoritet* Erbämpter oder der
gleichen *Singulariteten* vnd *Proprieteten* fürfallen/ ſo auß vnwiſſenheit nicht
recht geſchrieben/ in der *Correctur* auch angeregter vrſachen halben nicht zu
ändern müglich/ ꝛc. Als wolte der großgünſtige Leſer ſolcher/ wie auch/ was in
der Eyl vberſehen/ ſeinem vernünfftigen wiſſen nach/ vnbeſchwert ſelbſten
Corrigiren, Endern vnd verbeſſern/ ꝛc. Angeregter vrſach halben auch/ vnnd
das bey der Nacht eylend gefertigt werden muß/ zum beſten verſtehn/ auff vnd
annemmen/ ꝛc. Hiemit von dem Allmächtigen Gott ein frewdenreiches
Glückſeliges Newes Jahr/ beſtändige geſundheit/ vnd alle Wolfahrt/
den Großgünſtigen Leſer/ nach jedes *authoritet* vnder-
dienſtlich dienſt: vnd Freundlich wünſchend/

Johann Carolus

The foreword of Johann Carolus' newspaper
[To the] Most Honorable Reader: By the grace of the Almighty, we start a New Year. I will continue with the production of my ordinary newspaper, as I have for several years. The newspaper is going to be continued by the grace of God, as sure as I have got the [information] and as I will get further [news]. Sometimes there may occur errors and incorrectness; they may happen due to unknown names of places or people; they may happen due to my lack of knowledge of the correct denomination of the authorities; they may be spelled wrongly because I do not know every single information and property [on behalf of the aforementioned]. [I am sorry that] I cannot provide corrections under the circumstances [of production]: I have provided my work by night in a hurry. Therefore, the most Honorable Reader shall make corrections on his own; when he is going to follow his better knowledge and information he shall improve [my printings] without hesitation. Because of the haste at night, I tried to understand [the received information] with best intentions. Thus, I wish to You, Most Honorable Reader, a happy New Year by the grace of the Almighty God, good health, welfare and every authority's good services and friendliness.
Johann Carolus

Carolus was no journalist; instead, he received the mother copy of a handwritten newspaper from an unknown correspondent in the Imperial City of Augsburg. Welke estimates the price of that mother copy was 15 to 20 fl. a year. Carolus had some subscribers; the exact number is not known; in his request he calls them "several gentlemen" (etlichen herren); the meaning of several (etlich) in the Straßburg region at that time was more than five but less than ten; it is reasonable to assume eight or nine subscribers. Carolus sold a single copy for 12 fl. Therefore, it seems reasonable to assume 20 fl. rather than 15 fl. for the mother copy in 1605. Carolus' handwriting style was not easily readable; therefore, he engaged some students for the copy job. Welke estimates that the copiers cost 30 fl. a year. Despite his investments, Carolus made profits through his handwritten newspaper business. He was able to repay the interest rent for the loan and the annual repay share of the debts.[45]

45 In table 10, there is no row for the price of the paper. When buying the bookshop, Carolus had bought such a tremendous quantity of paper that he would have been able to print his newspaper for 100 years (Welke, 2008, p. 80) because only small numbers of sheets of paper were required. Therefore, the paper price calculation vanishes in the yearly rates of loan repay.

Table 10: Alternative calculation for the first printed newspaper in 1605 (in florin)

	written newspaper	*printed newspaper (1st year)*	*printed newspaper (1st year, alternative calculation)*	*printed newspaper (20th year)*	*printed newspaper (20th year, alternative calculation)*
mother copy	20	20	20	15	15
copy writers/ printers and typesetters	30	30	30	30	30
sub-total	*50*	*50*	*50*	*45*	*45*
single copy price	12	6	8	3.33	3.33
number of subscribers	8	30	30	100	150
sub-total	*96*	*180*	*240*	*333.33*	*500*
profit	**46**	**130**	**190**	**288.33**	**455**
in percent	92 %	260 %	380 %	541 %	911 %

Thus, Carolus' handwritten newspaper business was quite successful. Nevertheless, he tried to improve his return on investment. So he had the idea of a printed newspaper. The data for that business is pretty poor for the first year. However, the essentials cannot have changed much, when compared with the written newspaper business: The mother copy cost the same (20 fl. a year). Instead of student copy writers, Carolus had to pay for printers and typesetters. On the one hand, they were more expensive than students, due to their skills. On the other hand, their wages did not produce extra costs, because Carolus had hired them for his normal book printing business; otherwise, and without the extra job of the newspaper, his typesetters and printers might have been idle. So, Carolus acted almost like a modern entrepreneur: he condensed the work of the laborers. Therefore, one could reason that the typesetters and printers did not cost anything (extra) for Carolus. Instead, let us assume the same total wages as for the students (30 fl. a year).

Carolus reduced the single copy price and expanded the number of subscribers. Nevertheless, in the beginning he had not decreased the price much, for he sold a printed copy to the Council of Colmar for 12 fl. Even later, he did not modify the price, but rather delivered several extra copies to some members of the council. Overall, it seems quite reasonable to assume that the reduction margin was almost equal to the reduction ratio of the mother copy's price, when compared to the handwritten copies' price. That might have been six to eight fl. A reduction to eight fl. a year seems the most convincing in the beginning. With 30 subscribers in the first year of newspaper printing, Carolus may have enhanced his profit to 130–190 fl.

Figure 11: Edifice of the Council of Colmar (main building and side wing)

Note: The building may serve as a symbol for the first known subscribers of newspapers; they were "etlich herren", i.e. some noblemen, patricians and decision makers. Furthermore, the council's court represents peculiarities of newspaper reception at the beginning of the 17th century: a mixture of private and official reading; the reading rooms supposedly located on the 2nd floor.
Fotos: Copyright 2015 by Rudolf Stöber.

During the Thirty Years' War, the newspaper business disseminated all over Germany. It was crucial for people to get reliable information quickly. Therefore, many newspapers were founded in other towns and cities. The circulation of the newspaper rose, too. Welke estimates 100–150 subscribers of the Carolus newspaper during the 1620s. From several indicators, we can assume an average copy price of 3.33 fl. in that period: Carolus sold his newspaper directly for 4 fl.; intermediated by post service, he sold them to the mailmen for 2 fl. Furthermore, it is reasonable to calculate reduced prices for the mother copy. On the whole, Carolus may have made a profit between less than 300 and more than 450 fl. a year in the 1620s.

Provided with the calculations in table 10, we can estimate the efficiency gains for both parts of the media system: for the recipients (*rmd*) and for Carolus himself (*cms*). The total efficiency gain for all subscribers is the result of the number of subscribers (rising from 30 to 100–150) multiplied by the single copy's price reduction (compared with handwritten copies: ranging from 4 [1605] to 8.66 [1620th]). Therefore, the efficiency gain of all subscribers rose from 120 fl. to 1 300 fl. The efficiency gain of Carolus is the result of a subtraction: the printed newspaper profit minus the handwritten newspaper profit equals his efficiency gain. Even in the worst case scenario, Carolus' profit rose threefold, approximately. In the best case scenario, his profit rose fourfold, in the beginning. At best, the profit doubled again until the 1620s. In relative efficiency gains this means that at best in the beginning, Carolus and his buyers took almost an equal share in efficiency gains. Twenty years later, the share had shifted to 20 (*cms*, i.e., Carolus) to 80 (*rmd*, i.e., subscribers).

Table 11: Efficiency gains (in florin) for Johann Carolus and the purchasers of his newspaper (1605/1625)

compared to handwritten newspapers:	*printed newspaper (1st year)*	*printed newspaper (1st year, alternative calculation)*	*printed newspaper (20th year)*	*printed newspaper (20th year, alternative calculation)*
efficiency gain *rmd*	180	120	866.67	1 300
efficiency gain *cms*	84	144	242.33	409
sub-total efficiency	*264*	*264*	*1 109*	*1 709*
efficiency share *rmd*	68.2 %	45.5 %	78.2 %	76.1 %
efficiency share *cms*	31.8 %	54.5 %	21.8 %	23.9 %

Finally, a rough calculation of the gain in effectiveness shall finish the Carolus example. As long as the number of printed newspapers was as low as (or only moderately higher than) the number of handwritten copies, there was no gain in runtime effectiveness. Welke suggests half a day's work for the copy writers. The typesetters and printers did it in a little bit less time. The result was the same: written or printed copies were disseminated on the first day. The reception from the subscribers depended on the runtime of the distribution service. That varied strongly; therefore, the calculation neglects these differences. The result becomes different with 30, 100 or 150 copies. With 30 copies, the same number of writers would have had to work for one day and a half. The dissemination would start on the second day, at the earliest. The process of typesetting and printing would not have changed: so the effective dissemination speed would have doubled. With 100 copies, the writers would have had to work for five days. The dissemination could not start before the sixth day, so the effective dissemination speed would have accelerated six times. And with 150 copies, the writers would have had to work for seven and a half days. The dissemination could not start before the eighth day: the effective dissemination speed would have accelerated eight times.

A third example: The next table illustrates the differences in efficiency gains in parts and the increase of effectiveness for the whole. One of the earliest broadsheets with international news content serves as the starting point for a calculative approximation: the *Newe Zeytung auß Presillg Landt*, i.e., *News from Brazil*. The broadsheet exists in different versions. One is handwritten, another is printed without illustration, and a third version contains textual and pictorial information.

Figure 12: News from Brazil (*Newe Zeitung auß Presillg Landt*, ~ 1515)

Copia der Newen Zeytung
auß Presillg Landt.

Item wist das auff den Zwelfften
tag des Monadts Octobers Ein Schiff auß Presillg
landt hye an ist kummen umb geprech der Victualia/So dan
Nono vñ Cristoffel de Haro vnd andere gearmirt oder gerüst
haben. Der Schiff sein Zway/durch des konigs von Portugal
erlaubnuß umb das Presilg landt zubeschreiben oder zu erfaren
Vnd haben das Lanndt in Sechs oder Syben hundert meyll
weyt beschribiert/dann man das vor wissen hat gehabt. Vnnd
da sie kommen sein ad Capo de bona speranza/das ist ein spitz
oder ort so in das meer get/gleich der Nort Affril/vnd noch ein
grad höher oder weyter. Vñ do sie in solche Clima oder gegent
kommen sein Nemlich in Viertzig grad hoch/Haben sie das Pre
sill mit ainem Capo/das ist die spitz oder ein ort/so in das mer
get/funden. Vñ haben den selbigen Capo umbseylet oder umb-
faren/vñ gefundē/das der selb Calfo gleich ist gangen wie Eu
ropa leyt mit dem Syt ponente levante/das ist gelegēheyt zwi
schen dem auffgangk oder Ost/vnd nydergangk oder West/
Dann sie haben auff der anndern seyten auch die landt gesehen/
Als sie bey Sechzig meyllen umb den Capo kommē sein/zu ge
leicher weyß als weñ ainer in Levanten fert/vnd die stritta de
gibilterra passiert/das ist/furfert/ oder hyndurch einfarn/vnd
das landt von Barbaria sicht. Vnd als sie umb den Capo kū
men sein/wie gemelt ist/vnd gegen vns Nordwestwertz gesey-
let oder gefaren haben. Do ist vngewitter so groß worden/auch
windt gewesen/das sie nicht weyter haben kunnen saylen/oder
faren. Do haben sie durch Tramōtana/das ist Nort/oder mit-
ternacht/wider her vmb auff die annder seyten vnd Costa/das
ist landt/von Presill müssen faren. Der Piloto/das ist der schif-
fuerer/oder Schiflayter/So mit dysem Schiff gefaren ist/ist
mein fast gůt freundt. Ist auch der berümbtest so in der konig
von Portugal hat. Ist auch etlich Rayß in India gewesen/der
sagt mir vnd vermayndt/das von sollichem Cabo dye Presill/
das ist ein anfangk des Presill landt/vber Sechshundert meyl
gen Malaqua nit sey. Vermayndt auch in kurtzer zeyt durch so
A ij

The content of the broadsheet is relevant for the costs, but it is not relevant for the runtime calculation. The runtime calculus may serve as a proxy for the effectiveness gains of the whole communication system. Transmission time for news has decreased dramatically: from the beginning of early modern time, to the beginning of the 20th century, to the beginning of the 21st century. It is not necessary to prove this fact, but the key assumptions have to be explained: in early modern time, ships did not sail on schedule. Due to trade winds and torrents, some transatlantic passages were faster than others. Within four months, delayed by calms, storms and other negative factors, a typical naval vessel of that time, sailing from South America, could easily arrive at Europe's shore. Within the four months, there was one month's stay at the Cape Verde Islands for water and food supply. From Lisbon, it usually took some 6–8 weeks into the heart of Germany: Augsburg. Even a high-speed transmission by dispatch riders took at least 2 weeks. Therefore, the range between the fastest and the regular runtime of news could be 4–6 months.[46]

46 However, this was in use only when needed for most urgent affairs; dispatch riders were not in regular use. Contrarily to early modern times for both telegraphy and Internet communications, regularity and high-speed transmission is no contradiction. The fastest runtime for communication from Brazil to Augsburg at the beginning of the 16th century took at least 4 months.

Table 12: Developments in communication's costs and runtime

communication	*number of words*	*runtime (proxy for effectiveness)*	*costs for the recipient resp. user (proxy for efficiency)*
broadsheet "News from Brazil" (~ 1515)	~ 1 250 words[47]	about 6 months (4 by vessel from Brazil, 2 from Lisbon to Augsburg)	4 hours work of a craftsman (= 80–100 € today)
telegram (1905)	the same[48]	about 12 h	3 750 M[49] (= 10 000 hours of work[50] of a craftsman, = 200 000–250 000 € today)
internet communication (2015)	the same	1 minute[51]	1 €-Cent[52]

The imperial city was an important news node of that time. The next reference point of time (at 1900) appears to be somewhat contrary to intuition: because telegrams – even when transmitted at the speed of light – did not reach the recipient immediately. The sender of the telegram might have sent an errand boy to the closest telegram station; there, the staff transmitted the telegram; at the receiving station, the process was reversed; at last, an errand boy or mail carrier delivered the telegram to its final destination.

Today, any Internet communication may reach the recipient all the way around the world within only a minute's delay, if the recipient is online at the same moment. The acceleration factor between 1500 and 1905 is 360 to 1; the factor between 1905 and 2015 is about 720 to 1. Roughly calculated, in the last century the acceleration factor was twice as big as the factor for the four centuries before. Compared with half a millennium ago, the runtime has decreased by the factor of a quarter of a million to one. Further accelerations scarcely seem possible, because the runtime has reached its natural limit, almost zero.[53]

Transmission costs offer another calculation possibility. In general, the trend of information costs – and media costs – has decreased over time. New media, how-

47 Cf. full text in VD 16: http://daten.digitale-sammlungen.de/~db/bsb00009476/images/ (August 31, 2015).

48 The hypothetical assumption of such a long telegram is just for calculative reasons. The content of the early modern newssheet was merely soft news. In 1900, no one would have sent such a long telegram for entertainment reasons.

49 Every word of a telegram from Germany to Brazil cost more than 3 M. Telegram costs depended on the covered distance; at the same time, one word of a telegram in Germany cost 5 pennies (Meyers, 1909, vol. 19 [inlaid article "Telegraphentarif" without pagination]).

50 In other words, for an information runtime advantage of half a year (by the telegram from Brazil), an artisan would have had to labor for more than 3 years (10 hours a day, six days a week, no holidays). I calculated the average wage/h as 37 pennies. The calculation of the average derives from the average wages of some 40 industrial sectors in Berlin-Brandenburg in 1908; the sources derive from district chiefs of civil administration.

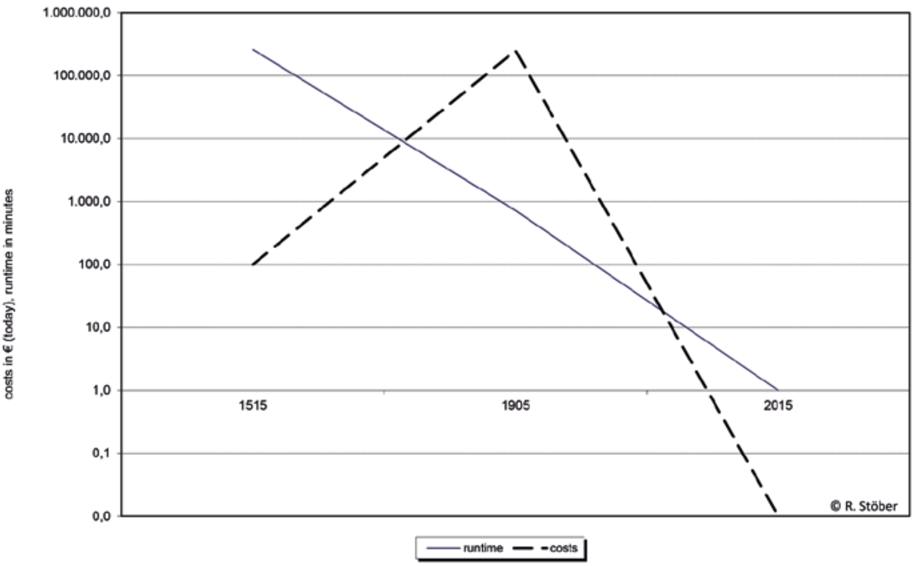
51 For calculative reasons.

52 For calculative reasons.

53 The perfect fit of the acceleration ratios can be overestimated. But, even if the margins of the assumptions are too wide for an exact calculation, the trend line indicates real changes.

ever, can turn the trend line, temporarily. Compared to the newspaper cost decrease during the 19th century, telegraphy was something different; it changed the game because news transmission by telegraph increased dramatically. The costs of the infrastructure were immense; the first installation attempts of a transatlantic cable, in the middle of the 19th century, became a financial disaster. At the end of the century, however, many overseas connections existed. The costs for refinancing the investments caused expensive telegram costs at the beginning of the 20th century. A telegram was (roughly) 2 500 times more expensive (on the basis of wages) than its equivalent at the beginning of the 16th century. Even calibrated with the runtime decrease, it was seven times more expensive. From that point of view, telegraphy was less efficient than early modern information transport. (As suggested above, cf. chapter 4.3, at the start an innovation does not have to be as efficient as its forerunner.) The costs of an Internet communication of today cannot be calculated exactly. When compared roughly with 1905, we can suppose a decrease ratio of 1 to 25 million. Since the beginning of the early modern times, the information costs on the recipients' demand side have decreased more than 10 000 times.

Figure 13: The development of runtime and information costs between 1515 and 2015



This hypothetical calculation enables considerations on relative gains and losses. Apparently, the runtime development was in favor for the whole system, the transmission costs were not. The effectiveness of every new information infrastructure was of a higher magnitude than the effectiveness of the former. From the transmission costs' point of view, the development of efficiency did not follow the same unidirectional trend. When looking at the cost increases until 1905, it can be suggested that the *communicator media subsystem* pressed so hard on the *recipient media demand subsystem* that the latter had hardly more than 1/2 500 share of the efficiency gains of the whole system, while the previous took a little less than 2 499/2 500 share of the gains. In percentages: 0.04% for *rmd* and 99.96% for *cms*.

Obviously, this is an extreme calculation, because investments in infrastructure and the amount of maintenance costs are no part of the calculus. With the integration of investment or maintenance measures, the efficiency share shifts step by step from the *cms*-side to the *rmd*-side. Thus, in reality, the *cms* gains were not as huge and the *rmd* not as low as in the given example. The extreme calculation is due to the incomplete calculation of the *cms*-side investments: Neither the investments in transatlantic cables nor the investments in Internet infrastructures are included. Therefore, the calculated gains might have been true for "early adopters" in 1860. In 1900, however, the use of telegrams was no longer restricted to "early adopters"; instead, the use of telegraphy transformed into the phase of use by the "early majority"; the assumption of 1/2 500 share of the efficiency gains on the *rmd*-side is a strong exaggeration.

For example, the maintenance of the cable between Britain and the US cost 8 000 £ on average per annum between 1874 and 1900. In 1900, the installation cost for a nautical mile of transatlantic cable was 250–300 £ (Britannica, 1911, pp. 513–515). Therefore, the distance between Portugal and Brazil totaled 900 000 to 1 million £. That does not sound spectacular, but it is: While the British £ in the 19th century was the hardest currency in the world, the parity with the German Mark was 1:20.5. In today's prices, the installation of a transatlantic cable would cost ca. 120–200 MM € with annual maintenance costs of 1.6 M €. Due to maintenance costs, plus a huge telegraphy staff and a public service infrastructure of telegraph lines in Germany at that time,[54] the Postal Telegraph Authority accumulated deficits almost every year. Therefore, the realistic efficiency shares of *cms* and *rmd* have to be estimated as between a 50:50 ratio and a 30:70 ratio.

4.6 Further examples beyond (more or less exact) calculations

The given examples provide a scheme for the calculus of efficiency. All of them lack information; therefore, all of them are more or less speculative assumptions. To leave the mathematical approach, the next table tentatively presents more examples of a shift in efficiency attributions. They could be disputed, for they are pretty rough.

54 The Imperial Postal Service established telegraph lines everywhere, even in thinly populated rural areas with little telegraph traffic. That was the main cause for deficits in the postal budget.

Table 13: Efficiency effects caused by media switch

media switch from – to (date)	*effects on cms-side (positive +/negative -)*	*effects on rmd-side (positive +/negative -)*
oral tradition – writing (ca. 3500 BC)	"investment" in professional scribes (education) (-) time stability of communication (+)	"investment" in education of readers (-) time stability of communication (+)
scroll – codex (ca. 400 AD)	more complex manufacturing process (-) books became more expensive (+)	information retrieval became swifter (+) books became more expensive (-)
writing – printing a la Gutenberg (ca. 1450)	expensive investments in the "work of books" (-) huge ratio of the return on investment (+)	excellent readability (+); books much cheaper (+); more books at hand at the same time (+)
irregular postal service – regular postal service (ca. 1490)	expensive investments in the infrastructure (-) huge ratio of the return on investment (+)	regular information and news service (+) expensive service (-)
manual printing – rapid press and rotary press machines (ca. 1800–1900)	expensive investments in printing machines necessary (-) printing machines provide more output per hour (+)	newspapers became cheaper (+) positive impact on economic newspaper concentration (-)
postal service – electrical telegraphy (ca. 1850)	expensive investments in the infrastructure (-) huge ratio of the return on investment (+)	very expensive (-) fastest information and news service (+)
electrical telegraphy – telephone service (ca. 1880)	expensive investments in the infrastructure (-) huge ratio of the return on investment (+)	very expensive (-) direct personal and business communication (+)
manual typesetting – linotype/automatic typesetting (ca. 1900)	expensive investments in typesetting machines necessary (-) typesetting machines' output per hour much bigger (+)	newspapers became cheaper (+) positive impact on economic newspaper concentration (-)
vaudeville theaters – cinema films (ca. 1895/1905)	huge investments at the start (-) multiplied distribution channels (+)	theater tickets as expensive as cinema tickets (+/-) multiplied program supply (+)
wireless telegraphy – radio (ca. 1920)	huge investments at the start (-) multiplied distribution channels and business models (+)	investments in radio sets (-) permanent access to radio program supply (+)
cinema films – films on TV (ca. 1950)	huge investments at the start (-) continuous access to recipient market (+)	investments in TV sets (-) permanent access to TV program supply (+)
traditional telecom services – www (ca. 1990)	huge investments at the start (-) access provider business models (+)	investments in PC equipment (-) expensive Internet access (-) rapidly growing access to Internet sites (+)
traditional Internet services – social networks (ca. 2005)	huge investments at the start (-) huge data retrieval (+)	tremendous connectivity (+) sensitive data exploitation (-)

In general, the given examples show that the notions "efficiency gains" with respect to "efficiency losses" are not trivial. Sometimes the gain on one side is equal to the loss on the other side; sometimes a gain on the *cms*-side has no direct, but rather an indirect equivalence on the *rmd*-side; sometimes gains and losses are equal on both sides; almost every time, some advantage in efficiency is bought by another disadvantage.

For effectiveness, it is quite different. At the least, the bigger media switches caused a tremendous growth of information reach. In modern times, those were printing, newspapers, telegraphy, film, radio and the Internet. The growth of information reach seems to be an exponential function. The expansion makes the whole system more effective, not just some parts of it. The tremendous effects of digitalization are discussed widely (Shapiro & Varian, 1999; Anderson, 2007; Brynjolfsson & McAfee, 2014).

Humanity seems to be doomed by that increase; nevertheless, at least since early modern times, many critics have repeated complaints on that matter at the arrival of every new medium. Neil Postman, who despised the information overload as "cultural AIDS," uttered his lament at the dawn of the Internet, the most recent media switch.[55] Nevertheless, every jeremiad proved false when society got used to the new medium. So be it.

5. Final considerations

5.1 An integrative concept of ICM

This paper has developed an integrative concept of ICM. First, it did so by "excavating" the linked phenomena layer by layer to the core: information. Second, it integrated the concepts through a discussion of the stability and change of media and communication layer by layer. Here, two abstract concepts apply: efficiency (with effectiveness) and redundancy. Evolution inscribed them both into every process: into the evolution of life, into cultural evolution and, last but not least, into media evolution. Efficiency drives the momentum of change; effectiveness provides levers of reach that grow exponentially from layer to layer; efficiency is the cause, enhanced effectiveness is one of the consequences; and redundancy offers the necessary stability to the process of information transfer. Without stability in the reproduction process of genetics, the genes would go astray. Without stability in communication, the same will happen to societies.
Critics may argue . . .

- That there is neither stability in genetic transfer nor in communication. This is right and wrong at the same time. I do not want to discuss redundancy and change in genetics – both seem to be obvious. In communication, both stability and transformation are a matter of viewpoint.

55 Neil Postman's speech "Informing ourselves to death" at a congress of the German Informatics Society on October 11, 1990: https://w2.eff.org/Net_culture/Criticisms/informing_ourselves_to_death.paper (August 31, 2015).

- That I have used language twofold: first as a synonym for communication, then as *Proto Media*. Language obviously is both: considered as communication, it indicates substantial needs for information exchange (and was invented by nature many times[56]); looked at as *Proto Media*, it is a cultural tool (improved by mankind); *Proto Media* fits under many changing circumstances.
- That my use of the notion "media" is not precise, because it was applied to "languages" (*Proto Media*), pictures and scripture (*Basic Media*) and mass media (*Dissemination Media*). But there is really no blur, because the latter media refer to the former in a multiple redundant way (as seen above).

5.2 Dystopian scenarios and the ratchet effect

This article does not explain media impact, even if it gives some hints on effects of media's existence. It does not explain, where ideation or innovative ideas come from; however, the article has examined, when change is likely to happen: The efficiency-effectiveness alternation offers an explanation for evolution's oscillation between stasis and rapid change. As indicated above, the efficiency race with the game changing event at its dead end does not happen once, but repeatedly. The fundamental process has been looked at above, where the different layers of media were scrutinized (in chapter 2).

Through redundancy, inscribed into the evolution of media layers, humans preserve their cultural heritage. Language and other *Proto Media* prevent each member of human society from the repetition of old faults; no one has to start completely anew with his or her learnings. *Basic Media* enhance this ability; *Dissemination Media* improve that capability over and over again. With every layer, humanity's options multiply. Therefore, the layers of media prevent fall backs. Like the safety brake for elevators that was invented by Elisha Otis in the 19th century, the media layers provide a ratchet effect for human society, techniques and culture. The layers prevent fall backs; because of this, culture ratchets up; it gets locked in a state that is more advanced than the previous one (cf. Tomasello, 2014).

Of course, the ratchet effect depends on some different parameters. As no safety brake will prevent an elevator from tumbling down in the case of the collapse of the building (for example, in an earthquake); a catastrophe that is big enough might crush the achievements of human culture. Therefore, I suggest once more discriminating between effectiveness on the one side and efficiency on the other. And again, redundancy comes into view.

From my point of view, the ratchet takes effect in a more fundamental way when the dimension of effective reach is considered. That kind of safety brake prevents fall backs, even in major disasters (like wars). When times are peaceful, when society, culture and economy develop prosperously and constantly, the striving for efficiency provides (less) effective safety brakes in smaller calamities.

56 Besides humans, all kinds of animals communicate (from insects [ants, bees . . .] to mammals. As recent biological research indicates, even plants seem to exchange information through chemical signals.

In general, all ratchets are the more failsafe-proof, the more redundant the evolutionary achievements are.

For the dimension of effectiveness, great fall backs are prevented by basic innovations. The most important basic innovations in the evolution of communication created *Proto Media*, *Basic Media* and *Dissemination Media*. Furthermore, three (somewhat smaller) basic innovations happened during the history of *Dissemination Media*: the innovation of the periodical press, the basic innovation of analog electronic media (telegraph, telephone, film, radio, TV) and the innovation of digital media. All of them provided society with other cultural safety brakes.

And there is a hierarchy from the older to the newer media: supposedly, the older will survive much longer and much bigger catastrophes. No human society, even after a nuclear disaster, would forget the concepts of digital media, (analog) electric media or press media. Nevertheless, the infrastructure of modern *Dissemination Media* might be eclipsed due to the failure of our technical civilization: a post-disaster humanity can preserve the concepts of digital media without having the concrete Internet infrastructure; a battered society can have the concepts of TV and radio still in mind, but without radio or TV networks in existence. A fall back into the times of the primitive periodical press may happen; but the concept of the social institution "press" will not be forgotten, unless the (technically) advanced civilization becomes extinct.

It is even more unlikely that *Basic Media* (writing, symbol manipulation) will be forgotten. Nevertheless, a seminal catastrophe might cause the failure of high culture and a fall back into a primitive (Neolithic) state of culture. All in all, it is very likely that writing and painting will prevail much longer than modern *Dissemination Media*.

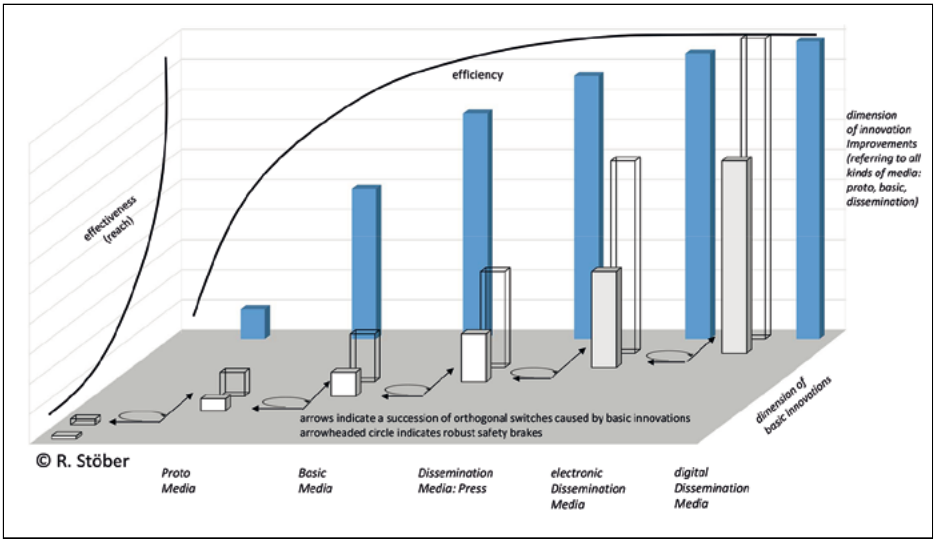
The extinction of *Proto Media* is the most unlikely event. That fall back, the loss of language and gesture, would mean the extinction of humankind, itself.

In short, every basic innovation works as a safety brake. But the older ones are much more stable and fail-safe – due to the redundant repetition in the newer media. And they have proved so many times, until now.

With innovation improvements, this is quite different: The ratchet seems to be less robust where efficiency driven improvements are concerned. Efficiency driven improvements are going to become smaller with every *n+1* improvement.[57] Most of these improvements add more complexity to the media infrastructure. A surplus in efficiency, complexity and comfort largely depends on the stability of the circumstances. Undisturbed redundancies provide that stability; (smaller or bigger) disturbances may trigger smaller or bigger backlashes. All infrastructures will crumble when not maintained. (Maintenance is a technical synonym for redundancy.) In a somewhat simplified mode, this looks like this (figure 9, revisited):

57 Cf. figure 7.

Figure 14: The safety brakes of the redundant layers of *Proto*, *Basic* and *Dissemination Media*



Note that the blue columns (the limited efficiency) have to be applied to each basic innovation; they ought to be repeated six times on the z-axis; the effective reach of each newer basic innovation is bigger than that of an older. Therefore, the redundant layers of media provide a threefold advantage: effectiveness in information reach (input and output), efficiency in information processing (throughput), and stability of culture (tradition).

5.3 The next game changing point is yet to come

What years are yet to come?

The reasoning about the longevity of media in the paragraphs above can be checked with a statistical hypothesis; with the Δ_t claim of J. Richard Gott III (professor of astrophysical science at Princeton), the prospects of media existence can be estimated. He called it the Copernican principle, for "it was a mistake to assume […] that we occupy a privileged position in the Universe" (Gott, 1993, p. 315); accordingly, the premise of the Copernican principle means that we live in normal times, not in an exceptional one. Considering that we live within a certain confidence interval of the whole lifetime of a cultural artifact or technique, say within 95% of its lifetime, at a minimum, 2.5% of the artifact's lifetime has expired before our time point of observation, and at a maximum, 97.5% of its lifetime can follow hereafter. Turned upside down, the likelihood of a maximum of 97.5% of elapsed lifetime and a minimum of 2.5% lifetime yet to come is also within the range of probability.

Projected onto the whole lifetime of automobiles, that means: the automobile was invented approximately 125 years ago. Supposing 2.5% of the total lifetime of the artifact has elapsed until now, humanity might use devices like the automobile for the next 5 000 years. Supposing that at the present time, 97.5% of the automobile's lifetime has elapsed, all automobiles might go out of use within the next three years and a quarter. This example illustrates both the use and the limit of the Copernican principle. On the one hand, the likelihood of the total lifetime of automobiles as being between 3 and 5 000 years is pretty plausible. On the other, most of the individual cars in use today will functionally exist for more than the next three years. To rephrase the problem: expired time as the only condition of life expectancy is one-sided. Nevertheless, the estimates in the next table confirm that cultural techniques are the more robust, the more they have proved their stability in the past.

Table 14: The likelihood of the prospects of media life

media	*life Expectancy*	*explanation*
language and gestures (*Proto Media*)	for some more thousands up to millions of years	Language is a criterion for the existence of humanity. We do not know when the first men started to use an elaborate code; presumably, it was (100 000 to) 200 000 years ago. Therefore, there is a likelihood of 95% that language will survive between (2 550) 5 100 and (3.9) 7.8 MM years, roughly calculated.
writing and paintings (*Basic Media*)	from more than 100 up to more than 1 M years	*Basic Media* is a criterion for high culture. Evidence for writing is as old as 5 500 years; evidence for elaborated paintings 35 000 years. Therefore, there is a likelihood of 95% that *Basic Media* will survive a minimum of 140 to a maximum of 1.4 M years.
modern *Dissemination Media*	from less than 20 to more than 20 thousand years	Modern *Dissemination Media* started with Gutenberg almost 600 years ago. Therefore, there is a likelihood of 95% that the press will survive at least 15 years. At its best, the press will survive 24 000 years from now.
smart phones	from a quarter of a year to 400 years	The most recent cell phones (smart phones) have existed since 2006. Therefore, there is a likelihood of 95% that within the next year or within the next some 100 years another communication device will substitute for the functions of a smart phone (maybe a sim-locked chip implant).
wireless Media	from a minimum of 0.5 to a maximum of 7.8 MM years	What is wireless media? Besides smart phones (look above), cell phones are wireless. Digital cell phones started ca. 20 years ago. The analog predecessors (telephones in cars) existed even in the 1950s. Wireless telegraph and telephone was in military use in World War I. However, language (and drums and smoke signs) are "wireless," too. Therefore, the 95% rule indicates an even wider range of life expectancy than the estimates before.
the "singularity" of Artificial Intelligence (AI)	not reached yet (life expectancy after AI-achievement ranges from instant Armageddon to eternity)	The achievement of AI can enhance humankind's effective reach at infinitum; with equal likelihood, it will destroy mankind at once. But obviously, this reasoning is like looking into a fortune-teller's crystal ball. Science fiction literature and films provide abundant examples of self-fulfilling or self-destroying prophesies. As Moore's law give the latest example of an efficiency race coming to its dead end, there remains the inevitable question: What game changing point comes up, next? I would bet on AI; but will I not risk my pension on that; at least, I am not sure to live long enough to see it coming; and if I should do so, I am not sure, whether that is wise.

5.4 Change and stability in culture and beyond

"Medium" obviously has a wide range of meanings. Since all media are social institutions, all of them have specific functions for human society. My claim is that the first task of every media layer is to provide social stability (by coordination). One may coin this task as a "second level observation." The second task aims at a tremendous expansion of reach: humankind is, for better or worse, the master of Earth because of his effectiveness; in communication, men have outrun all other species; for every media reduced search costs. With every layer of media, humankind assumed a much more powerful lever. From the human point of view, this was a win-win situation. For all other species, it was, at best, a zero-sum game. Mostly, they lost.

With the stability of communication, it is thus: de Saussure discriminated between language and speech. It is apparent that concrete speech varies from speech act to speech act. Language – English, French, German or any other language – seems stable, although everyone may have noticed changes; the language of an older person is not quite the same as the language of the youth. Even though language is more stable than speech, it is evolving. The stability of communication is derived from two aspects: a) Language appears much more stable when we consider the redundancy rates of ancient and modern languages (as seen above). Human languages' redundancy rates (50%–70%) indicate an optimum: our ancestors discovered the most efficient form of communication by language long ago. There is a necessary equilibrium between information density and communication stability; the range of redundancy indicates that the equilibrium is variable. b) Luhmann was right, here: there is no society without communication. We have to communicate ceaselessly. The continuity of communication implies many redundancies; we cannot restrict ourselves to just the news; if we did, we would fall into silence; our social life would collapse soon.[58]

There are, of course, other languages: some may be older, some may be younger than human languages and some may have evolved in a process of co-evolution. The other languages – mathematics, music, gestures and facial expressions – provide us with specific advantages. Mathematics is the language of rational logic; music is the best language for the transport of emotions; gestures are good at both the indication of affection and immediate danger; facial expressions provide knee-jerk reactions and, therefore, may be the most honest language of mankind.

Norbert Wiener stated that information is a function of time: any information and communication is a code; any code is a sequence in time. Redundancy, therefore, is necessary for all codes to provide time stability. More metaphorically speaking: redundancy bridges time and redundancy provides order. With efficiency, it is the other way around. The more efficient a system is, the less it disturbs the given order. That means that for the material component of media: Since matter and energy are complementary, the applicability of efficiency is apparent; all

58 Analogue to languages' optimum redundancy, I wonder: What are the limits of information overload, modern digital societies can afford? What is the best ratio for news, alternative views, repetition and tradition, so that societies can stay human and develop peacefully?

work is strenuous; the less work is necessary, the better and more efficient the material components of media run.

Efficiency and redundancy converge in negative entropy. It may be in question whether or not "entropy" – related to both information and evolution theory – establishes a semantic short circuit. I reject that objection. Two answers are possible: The first, a conservative one, hints at the formal language: negative entropy is no semantic short circuit because both redundancy and efficiency can be described by means of information theory; both are a function of time; time-bound entropy causes disorder – in physics and in information. Furthermore, in quantum physics, particle properties are a matter of observation, i.e., information; this may be applied to the space-time continuum in general. The second rejection, very speculative, reaches even further: The double relationship of negative entropy may point to deeper layers of reality. From this point of view, reality as such is information (cf. Tegmark, 2014). That is pretty close to the ideas in the *Matrix* trilogy, *The Thirteenth Floor*, *World on a Wire (Welt am Draht)* and similar science fiction films. Regardless of quantum physics, it will never be proven.

5.5 The logic objective: why there is no determinism

The most important objective of this paper, for me, was a logical one. I have often wondered how stupidly extrapolations of trends are sometimes deployed. Furthermore, I have wondered about deterministic views of (social) reality. Besides quantum physics, I have never had an idea that could be a fail-safe proof for a nondeterministic reality, until now: because of the limits of efficiency and because of the intensification of natural and cultural "metabolism," the predictability of change is void. While the competition for more efficiency is a dead end race, all competitions have to dramatically change the playing fields in the end. Sooner or later, provided there is enough time, change will occur (nature's time is infinite, man's is not). However, no one is able to predict the concrete prospects of change. Life and ICM are rather contingent. It seems clear that an axiom is the base of the proof: entropy is the cause of efficiency and, therefore, the driving force behind all this. Unfortunately, no one can prove an axiom – by definition.

The point of reference defines efficiency attributions. However, are the attributions of efficiency just like a verbal analog of efficiency in physics? I regard the notion *efficiency* as no semantic short circuit; and so is the notion *entropy*. As long as action is involved, the discussion of media (seen as social structures) and communication (looked at as social action) displays the core of physical efficiency. Any action that gains the maximum output by investing the minimum input is efficient in the physical sense; all actions that have to overcome countermeasures are less efficient in some way or the other. Redundancies and repetitions are inefficient when repetition needs extra work despite the same output; every action or communication with the same output and without repetition requires less input.

But from another perspective, the presumed inefficiency is not so clear. As shown above, signal transfer (information) without redundancies is not possible because information is a time function; redundancy bridges time, is "louder" than white noise and overrules other disturbances of information transmission; therefore, it is interwoven with the most genuine form of human communication: language. From this perspective, *redundancy* is an instrument of *efficiency, when* in use *as seldom as possible* (under the given circumstances), *and* when redundancy is in use *as often as it is convenient* to prevent disturbances in the future.

Table 15: The equivalents of efficiency and effectiveness in different contexts and the link to physics

context	*the analog of efficiency and effectiveness*	*link to physics*
information	information without white noise	highly disputable because . . . : of Norbert Wiener ("Information is information, not matter or energy"): no link exists; of Max Tegmark[59] (reality is information): entropy is the link;
social action	social action without obstructive countermeasures	positively expressed: social action is effective when it is successful; it is efficient when the necessary work of input can be minimized; negatively expressed: from every countermeasure, an (otherwise unnecessary) social action is derived;
social structures	institutionalized social action without destruction	positively expressed: social structures work effectively when they are reliable and stable; they appear to be efficient when social action is easier within than without social structures; negatively expressed: destruction makes reconstruction work necessary
communication	comprehendible exchange of information (at best, with mutual understanding)	positively expressed: communication, as a subset of social action, is effective when it is successful; it is efficient when the necessary work of input can be minimized; negatively expressed: when white noise and other disturbances hinder communication;
media system	reliable media services	positively expressed: media, as a subset of social structures, is effective when it provides stability; it is efficient when the necessary work of maintenance can be minimized; negatively expressed: destruction makes reconstruction work necessary.

59 Max Tegmark is a renowned Swedish-American cosmologist; he is the author of a popular non-fiction book in which he reasons that our observable universe and the different "multiverses" rely on information in a mathematical structure (cf. Tegmark, 2014, passim, esp. pp. 18, 293, 325).

The efficiency race is the main cause of evolution, enhanced effectiveness is the most important consequence of change. Efficiency and effectiveness provide the zero-sum part and the win-win situation – from the very first beginnings of evolution to the latest developments in our social environment. Redundancy guarantees the necessary stability for everything, from information to media and communication. The disputable table above is, therefore, a comment on some genuine fields of communication science. With the exception of the first row: There Wiener's and Tegmark's understandings of information seem to contradict each other. However, maybe there is a link via entropy; if that axiom is wrong, so will the derivations in this article be. However, it cannot be checked out; for once again, the incompleteness of formal systems comes into view – proven by Gödel (1931). While that is true for any sufficient complex system, therefore, it is true for information, communication and media. Even if everything may be uncertain, the meaning of change remains; evolution is inevitable, but its outcome is not.

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